CT Imaging of Nose and Paranasal Sinuses A Primer

Prof. Dr Balasubramanian Thiagarajan

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About the author

Professor Dr T Balasubramanian MS DLO is a former professor and Head Department of Otolaryngology Government Stanley Medical College Chennai India & former Registrar The Tamilnadu Dr M.G.R. Medical University is a senior otolaryngologist and practising surgeon with rich experience in the field. He has authored many books for the benefit of students and practitioners of otolaryngology. His websites and Mobile applications which covers various topics in otolaryngology has been an immense hit among students.

Android applications:

1. Otolaryngology online

2. ENT Prep

3. Imaging in Rhinology

4. ENT MCQ

5. ENT Instruments

About the Book

When I was rummaging through my things I found a huge treasure trove of CT images. I wanted to share them with everyone so that it could be of use. With this intention in mind I sharted cataloging and digitalizing them. The collection was so exciting I decided to use all of them in my book. This book has been authored with CT images of nose and sinuses from my personal collection.

Target audience:

Post graduate students in otolaryngology

Practising otolaryngologists

Post graduate students in Radiology

Axial, coronal and sagittal views of CT nose and sinsues are discussed for various pathological processes. Readers will be exposed to the art of viewing CT images sequentially.

Separate chapters have been devoted to the description of CT anatomy including various anatomical variations. Reader will be able to have a clear understanding of how to go about reading a CT sequential images of nose and paranasal sinuses. Lot of emphasis is placed on the art of reading coronal sections because this is the actual endoscopic view of the nasal cavity encountered by the surgeon. Towards this end 2 mm sections of coronal CT images have been included with appropriate description.

Since this book has been authored by an Otolaryngologist, the entire content of this book will be from the prespective of an otolaryngologist.

Comments can be mailed to: drtbalu@gmail.com

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Introduction

CT images of nose and paranasal sinuses have become common with the easy availability of the requisite equipment. These images really come in handy for the surgeon who performs surgery (endoscopic sinus surgery) in this area. It should be stressed that coronal sections of nose and paranasal sinuses CT serve as a road map for the surgery because it reveals the air cells as encountered by the surgeon on the operating table. Thinner the sections better it is. A 1 - 2 mm cuts would reveal almost all the ethmoidal air cells and the surgeon can study them cell by cell before embarking on endoscopic sinus surgery.

The advent of nasal endoscopic sinus surgery has really made treatment of chronic sinus infections that much easier. The surgeon can visualize and clear the diseased air cell mucosa retaining the normal mucosal lining. This ensures that healing process is real quick and the normal mucosal clearance mechanism resumes rather early.

The health and normal function of the paranasal sinuses and their lining mucous membrane depends on ventilation and drainage. Routine CT imaging of nose and sinuses would be easily picked up by CT there by ensuring that the surgeon is not surprised on the table and would always stay oriented. The anatomic variants if not taken into consideration would lead to intraoperative complications.

CT images also reveal the severity of the disease, the extent of involvement of various sinuses thereby allowing the surgeon to take an informed decision on the extent of surgery needed.

The area of concern would be the osteomeatal complex which acts as a drainage pathway for maxillary, anterior ethmoids and frontal sinuses. This area can be studied in detail in coronal CT images. The ideal role of CT imaging is to define non-reversible disease; that is the disease component that has not responded to the conservative medical therapy and requires endoscopic sinus surgery. It must be emphasized that administration of a course of antibiotics a few days before the scan, thereby eliminating the acute sinusitis component; usee of nasal decongestants 15 minutes before scan followed by blowing of the nose will ensure that maximal clearance of the sinus is achieved revealing just the refractory areas.

Their has been a few suggestions to reduce the total amount of radiation dose while performing CT imaging. Bone window settings would go a long way in reducing the radiation dosage to the patient.

Advantages of reducing exposure techniques include:

1. Decreased radiation exposure to the patient

2. Extended CT tube life

3. Reduced expense

Delineation of the individual components of the osteomeatal complex is critical to the correct interpretation of inflammatory diseases involving the nose and sinuses. Imaging while putting the patient in prone position provides an optimal view of the components of the osteomeatal complex, with the dependent fluid layering away from the osteomeatal complex unit. Supplemental coronal scans with the patient in supine rarely could be of help for complete pathologic characterization. A 3 mm slice scan is critical for optimal visualization of the osteomeatal complex components. Radiologists prefer to take 3 mm slices up to the level of the osteomeatal complex area and then follow it up with 5 mm contiguous sections through the posterior half of the sinues which include the posterior group of sinuses where the air cells are larger than that of anterior ethmoid group.

Studies reveal that scan angle is not important and as far as osteomeatal unit imaging is concerned it does not exist. With 3 mm and thinner slices the actual coronal angle is really insignificant. Imaging angle can be set to maximally avoid dental amalgam. Coronal images are attempted in all patients initially, with supplemental axial images through the lower maxillary sinus obtained only in the rare circumstances where dental amalgam aritifacts are rather severe. Full axial images with coronal reconstructions are used only in those patients who are physically unable to assume the coronal scanning position.

Scanning protocol for CT paranasal sinuses:

Patient preparation:

This is the key for eliminating reversible and medically manageable disease. This allows better delineation of anatomy and definition of chronic disease that would require endoscopic sinus surgery. Preparation include:

1. One full course of appropriate antibiotics

2. Continuation of oral antihistamines

3. Nasal decongestant packing 15 minutes prior to imaging which is followed by vigorous nose blowing

4. Steroids should be considered in allergic patients.

CT patient position:

Coronal imaging is performed with patient in prone position with head hyperextended resting on the chin. This keeps the free fluid out of the infundibular area. If patients are unable to maintain prone position or when images obtained in prone position are inconclusive, the supine position with head hyperextended over the edge of the table is used for coronal imaging.

Gantry angle:

Perpendicular to the hard palate to obtain direct coronal images. The actual coronal angle is not critical.

Scan extent:

Extent of the scan is posteriorly from the posterior margin of sphenoid sinus to anterior margin of frontal sinus.

Section thickness:

Initially 3 mm cuts were used. But currently 0.5 - 1 mm cuts are used. This will ensure that all the air cells can be studied. Variations of air cells if any can be studied extensively if thinner cuts are performed. Anterior thin cuts are very valuable as this wound ensure optimal visualization of osteomeatal unit.

kVp - Also known as kilovoltage peak. This is the peak potential applied to the CT scan tube which accelerates electrons from the cathode to the anode. Tube voltage, determines the quality and quantity of the photons generated. The first consideration when selecting kVp is to ensure adequate penetration and exposure which depends on photon number, photon energy, and tissue attenuation. The kVp used is 120.

Imaging algorithm - Bone window is preferred with maximum edge enhancement.

Image of CT scan machine

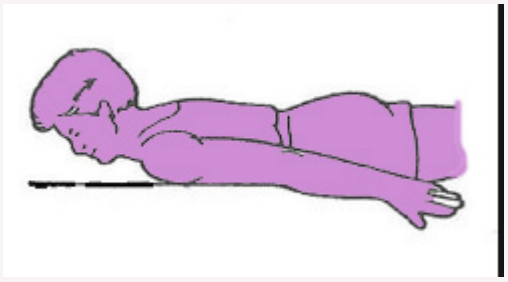

Image showing patient position while performing Coronal CT imaging of paranasal sinuses

Currently it is imperative on the part of the surgeon to study coronal CT images of nose and sinuses before embarking on endoscopic sinus surgery as it would provide the following useful inputs:

1. It provides the exact endoscopic view for the surgeon as he/she would encounter during the procedure.

2. It provides a good account of the anatomy of the lateral nasal wall and the ethmoidal air cells. Ethmoidal air cells are complex showing a large number of anatomical variants. Prior knowledge of these variants before surgery could go a long way in reducing the iatrogenic morbidity of endoscopic sinus surgery.

3. Routine CT imaging of nose and sinuses have enriched our knowledge about the complex anatomy of the lateral nasal wall and its variations. It should be pointed out that the entire anatomy of lateral nasal wall has been rewritten after studying these images.

4. It also reveals the extent of pathology of the lesion.

5. It serves as a road map to the surgeon.

6. Thin sections of CT images can be fed to a computer as used along with image guidance enabling the surgeon to have better orientation of the vital structures like the skull base, orbit etc during the endoscopic sinus surgery.

CT images reveal three colors:

1. Black - Air within the paranasal sinuses and nasal cavity are shown as black colored structures in CT images. Fat will also be seen as Black images

2. White - Bone is always rendered as white in CT images

3. Gray - Soft tissues and fluid are seen in various shades of gray in CT images

Currently CT images are taken in three dimension with 3 mm thickness. Some surgeons insist on 1 mm sections also. Three dimensions CT images are usually taken in the following planes:

1. Coronal - The surgeon's view

2. Axial view

3. Sagittal view

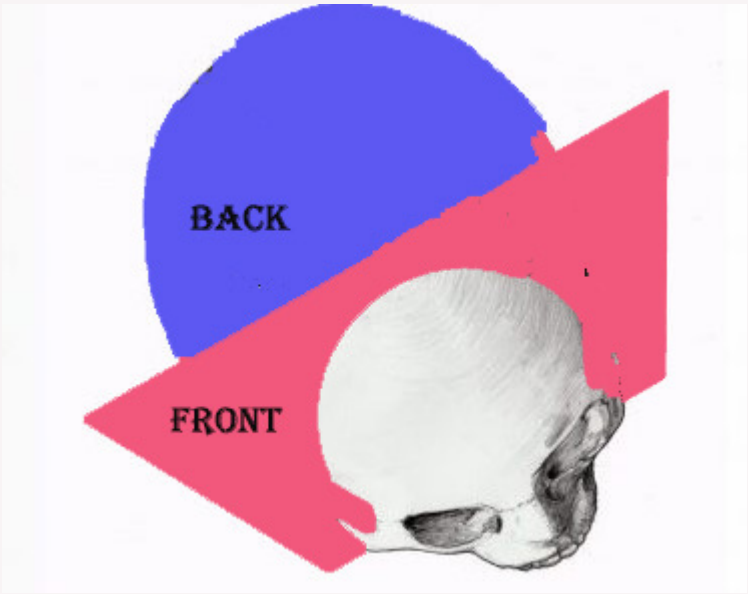

Image showing coronal plane of skull. Sections are performed from front to back

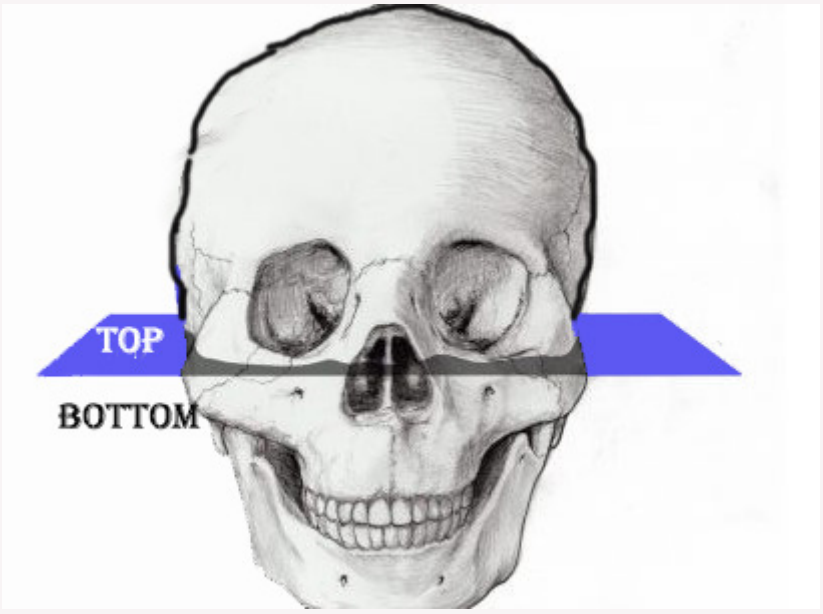

Image showing axial plane of skull. Here sections are performed from top to bottom

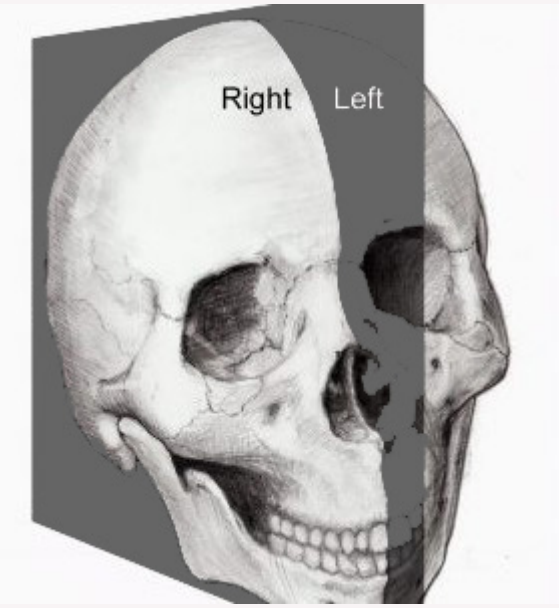

Image showing sagittal section of skull and it extends from right to left side

CT scan has the ability to characterize the paranasal sinus diseases along with their extension. It could also delineate the bony involvement of the disease. It also enables the surgeon to visualize the drainage pathways, anatomical and critical variants in the sinuses.

Sagittal CT scans are usually generated from the axial scan data using multiple thin overlapping cuts to reduce the noise level. Even though direct sagittal sections are ideal using special accessory table adopted for this purpose majority of the scan centres reconstruct axial scan data to generate sagittal images using computer software.

Anatomy of Nose & paranasal sinuses

Many references pertaining to anatomy of paranasal sinuses exist. The earliest such reference dates back to the work of Galen who described the presence of ethmoid air cells. Detailed description of maxillary sinus by Leonardo da Vinci in 1489, sphenoid sinus by Giacomo Berengario da Carpi in 1521, frontal sinuses by Coiter in the 16th century introduced the early anatomists to the presence of air cells around the skull bone.

Most modern and accurate description of paranasal sinuses could be attributed to the works of Austrian anatomist Emil Zuckerkandl during the 19th century. His description and illustrations really set the standard for current understanding of the anatomy of nose and sinuses.

Paranasal sinuses were first identified inside the bones of the skull by ancient Egyptians. Medical literature dating back to 3700-1500 BC provide evidence that Egyptians were familiar with the structure of maxillary bones and its sinuses. As per the Edwin Smith Papyrus (1600 BC), ancient Egyptians were interested in the treatment of nasal injuries and nasal fractures. They also used special instruments to remove the brain through the nasal cavity by breaching the ethmoidal air cells. Ancient Egyptians should be considered as pioneers of sinus surgery.

Next to the Egyptians, Greek physicians like Hippocrates, Galen, and Celsus recognized that the paranasal sinuses to be part of the skull. Hippocrates in his writings gave instructions on how to manage nasal polypi. He also provided detailed information on how to reconstruct nose injuries by repositioning the dislocated bones. He also indicated that in the process of producing voice, the air that humans breathe out passes thorough empty cavities inside the head and echoes. Aulus Celsus in his book titled 'De Medicina' provided a description of the surgical anatomy of the nose and the olfactory nerves passing through the cribriform plate of ethmoid bone.

Anatomist of the Renaissance, Andreas Vesalius (1514-1564) gave a description of paranasal sinuses in his work 'De Humani Corporis Fabricca'. Vesalius stated that these empty sinus cavities helped to reduce the weight of the skull bone and contributed to the formation of voice.

Nathaniel Highmore an anatomist by profession gave a detailed description of maxillary sinus and hence maxillary sinus is also known as antrum of Highmore. In fact he was the first anatomist to describe the maxillary sinus and draw a diagram of it. Highmore in his treatise included anatomica drawings of maxillary and frontal sinuses. he also described the close relationship of the maxillary sinus with the orbit, and the teeth of the upper jaw. He also noticed and documented that roots of upper teeth projected into the maxillary sinus.

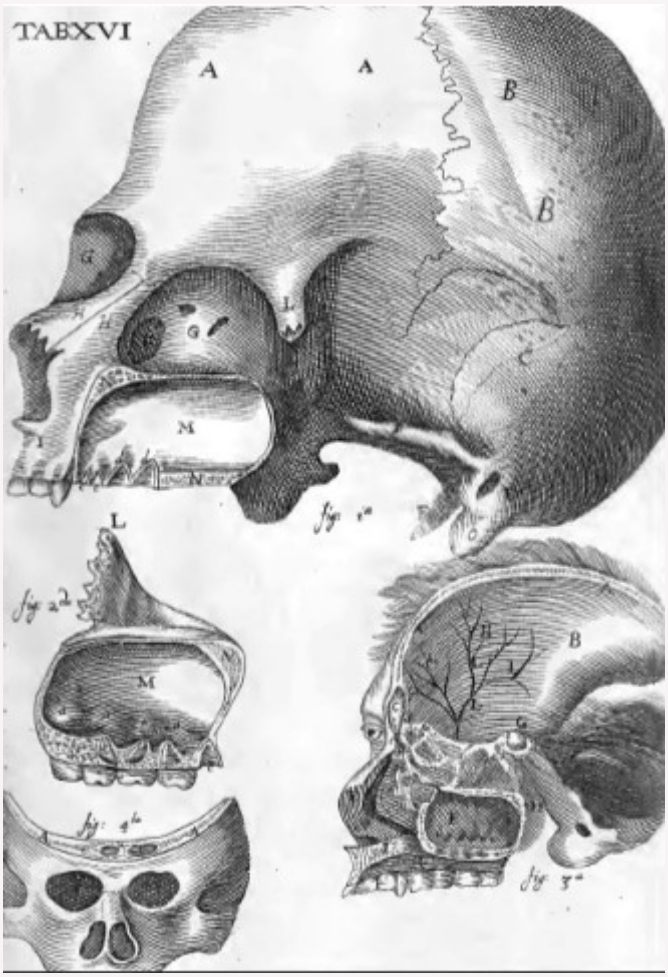

Image showing illustrations from Nathaniel Highmore's book 'Corporis Humani Disquisitio Anatomica'. Maxillary sinus is clearly demonstrated including the projection of upper dentition into it.

Harris Peyton Mosher dissected many cadavers and came out with an accurate description of ethmoid sinuses. He noted the close relation of ethmoid sinuses to skull base and orbit, he claimed that intranasal ethmoidectomy a surgical procedure prevalent those days was the easiest way to kill a patient.

With the common use of nasal endoscopes as a diagnostic and surgical tool, the anatomy of the lateral nasal wall has been completely rewritten. In fact the present description of the lateral nasal wall anatomy confirms with the endoscopic anatomy of the lateral nasal wall. The anatomy of the lateral nasal wall is highly variable, and a thorough understanding of the anatomy is a must before proceeding with any nasal endoscopic procedure.

Nasal turbinates:

The turbinates are the most prominent feature of the lateral nasal wall. They are usually three or some-

times four in number. These turbinates appear as scrolls of bone, delicate, covered by ciliated columnar epithelium. These turbinates sometimes may contain an air cell, in which case it is termed as a concha.

These turbinates project from the lateral wall of the nose. Out of these turbinates the following are present in all individuals:

The superior, middle and inferior turbinates. A small supreme turbinate may be present in some individuals. Among these turbinates the superior and the middle turbinates are components of the ethmoidal complex where as the inferior turbinate is a separate bone. Commonly a prominence may be seen at the anterior attachment of the middle turbinate. This prominence is known as the agger nasi cell. This prominence varies in size in different individuals. These agger nasi cells overlie the lacrimal sac, separated from it just by a thin layer of bone. Infact this agger nasi cell is considered to be a remnant of naso turbinal bones seen in animals. When the anterior attachment of the inferior and middle turbinates are removed, the lacrimal drainage system and sinus drainage system can be clearly seen.

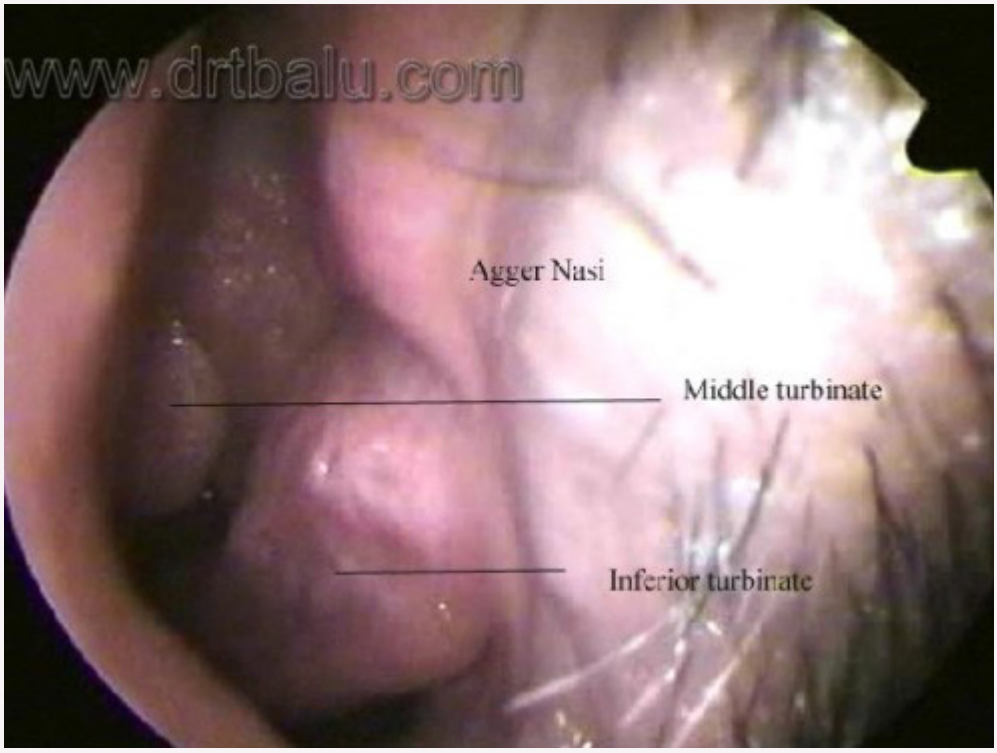

Image showing Endoscopic view of lateral nasal wall

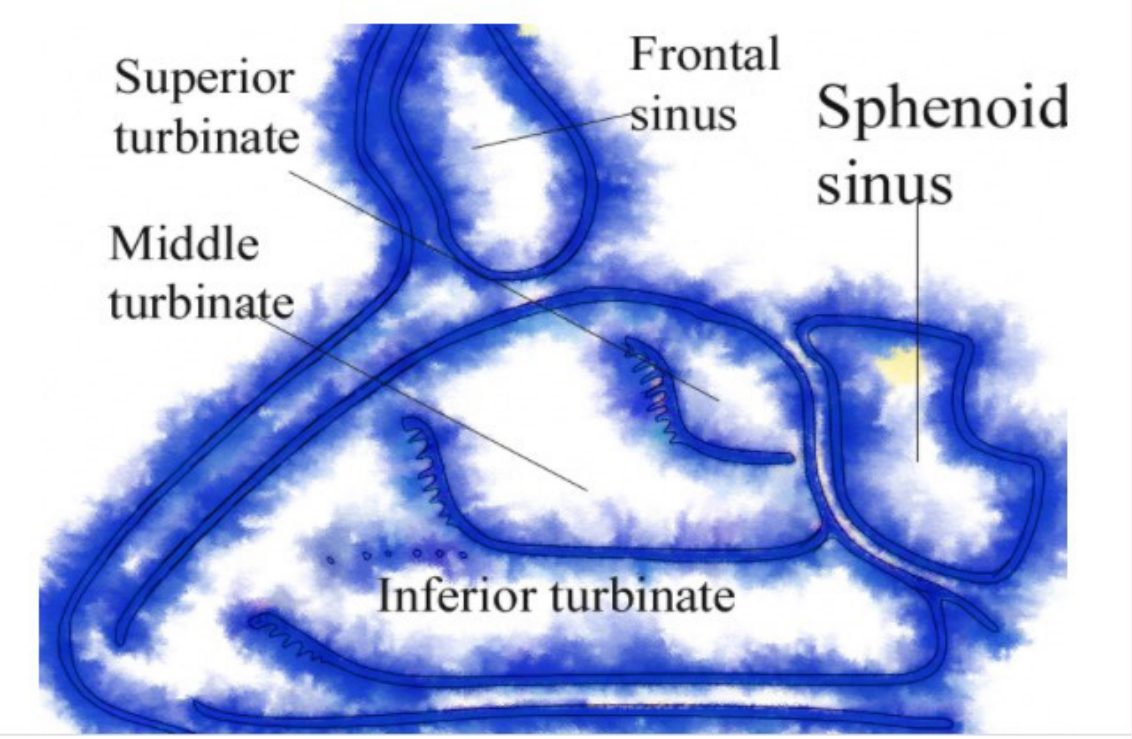

Image showing the turbinates in the lateral nasal wall

The inferior meatus is present between the inferior turbinate and the lateral nasal wall. The nasal opening of the naso lacrimal duct opens in the anterior third of the inferior meatus. This opening is covered by a mucosal valve known as the Hasner's valve. The course of the naso lacrimal duct from the lacrimal sac lie under the agger nasi cell.

The middle meatus lie between the middle turbinate and the lateral nasal wall. The middle turbinate is part of the ethmoidal complex. The sinuses have been divided into the anterior and posterior groups. The anterior group of sinuses are frontal, maxillary and anterior ethmoidal sinuses. These sinuses drain into the middle meatus, i.e. under the middle turbinate.

Uncinate process:

Actually forms the first layer or lamella of the middle meatus. The uncinate process is a wing or boomerang shaped piece of bone. It attaches anteriorly to the posterior edge of the lacrimal bone, and inferiorly to the superior edge of the inferior turbinate. Superior attachment of the uncinate process is highly variable, may be attached to the lamina papyracea, or the roof of the ethmoidal sinus, or sometimes to the middle turbinate.

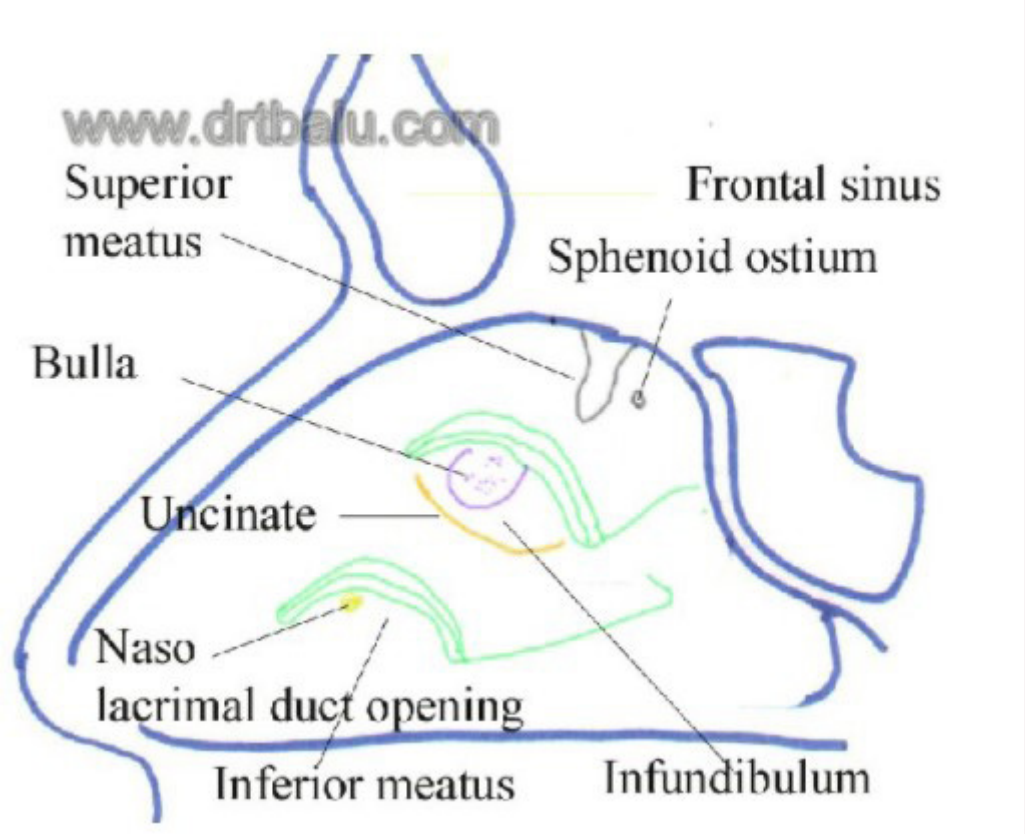

Image showing the lateral nasal wall after removing both inferior and middle turbinates

The configuration of the ethmoidal infundibulum and its relationship to the frontal recess depends largely on the behavior of the uncinate process. The uncinate process can be classified into 3 types depending on its superior attachment. The anterior insertion of the uncinate process cannot be identified clearly because it is covered with mucosa which is continuous with that of the lateral nasal wall. Sometimes a small groove is visible over the area where the uncinate attaches itself to the lateral nasal wall.

Type I uncinate:

Here the uncinate process bends laterally in its upper most portion and inserts into the lamina papyracea. Here the ethmoidal infundibulum is closed superiorly by a blind pouch called the recessus terminalis (terminal recess). In this case the ethmoidal infundibulum and the frontal recess are separated from each other so that the frontal recess opens in to the middle meatus medial to the ethmoidal infundibulum, between the uncinate process and the middle turbinate. The route of drainage and ventilation of the frontal sinus run medial to the ethmoidal infundibulum.

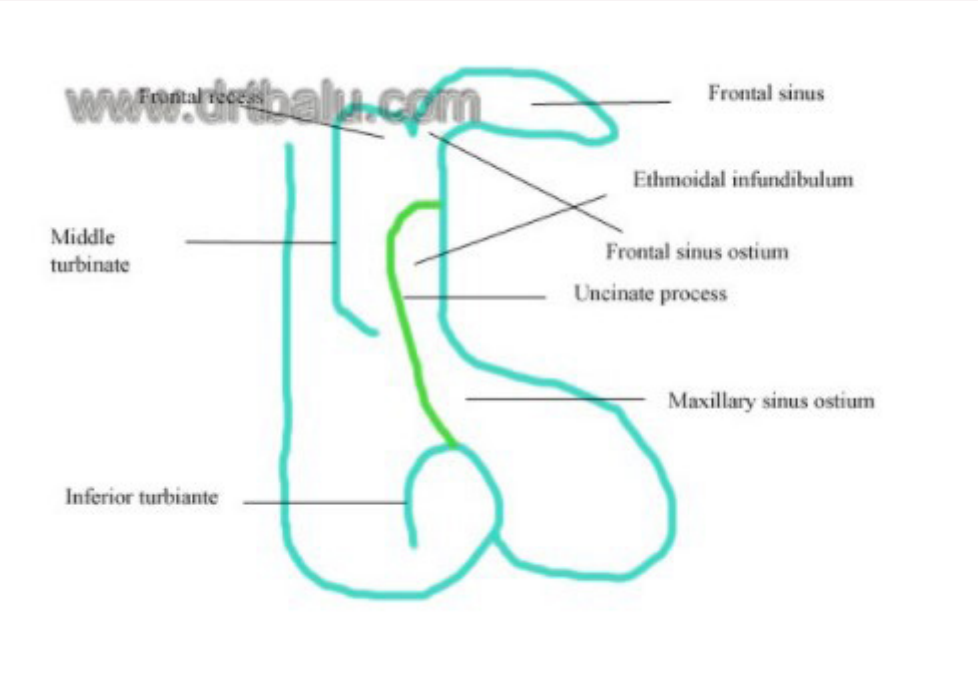

Image showing type I uncinate insertion where the upper end of the uncinate process could be found inserted into the lamina papyracea. The lower attachment of the uncinate is fixed i.e to the inferior turbinate. In this scenario the frontal sinus would drain lateral to the middle turbinate.

Type II uncinate:

Here the uncinate process extends superiorly to the roof of the ethmoid. The frontal sinus opens directly into the ethmoidal infundibulum. In these cases a disease in the frontal recess may spread to involve the ethmoidal infundibulum and the maxillary sinus secondarily. Sometimes the superior end of the uncinate process may get divided into three branches one getting attached to the roof of the ethmoid, one getting attached to the lamina papyracea, and the last getting attached to the middle turbinate.

Type III uncinate process:

Here the superior end of the uncinate process turns medially to get attached to the middle turbinate. Here also the frontal sinus drains directly into the ethmoidal infundibulum.

Rarely the uncinate process itself may be heavily pneumatized causing obstruction to the infundibulum.

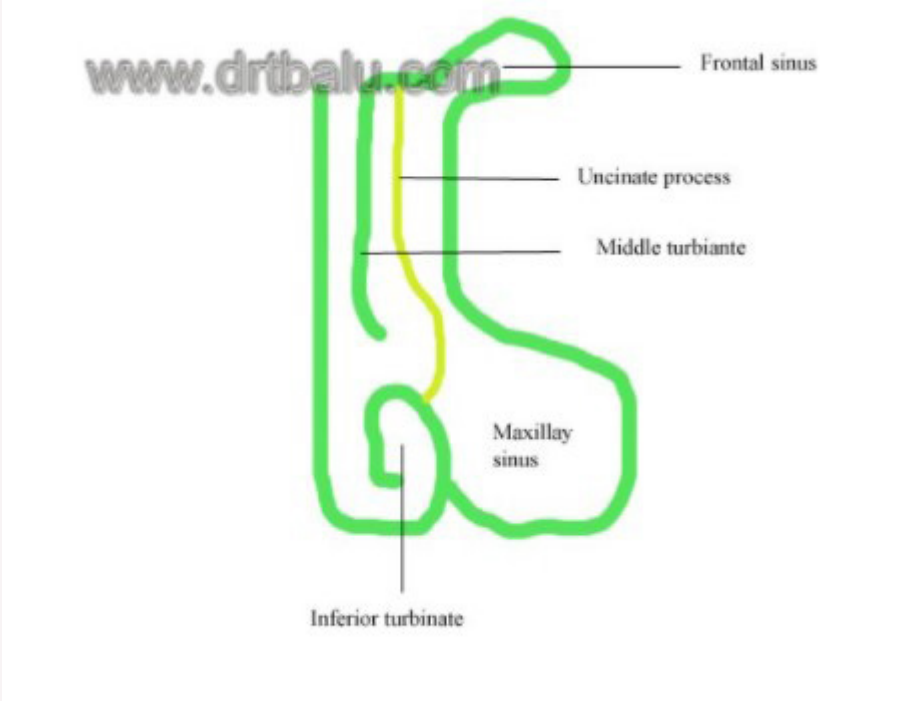

Image showing type II insertion of uncinate where superiorly it is attached to the skull base. In this scenario frontal sinus drains into the infundibulum

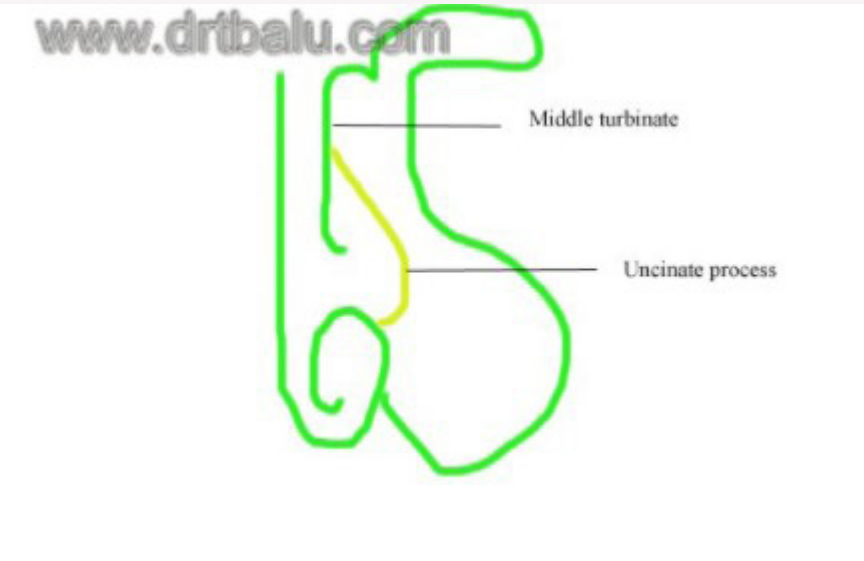

Image showing Type III insertion of uncinate into the middle turbinate. In this scenario frontal sinus would drain into the infundibulum

Ethmoidal infundibulum:

This is a cleft like space, which is three dimensional in the lateral wall of the nose. This structure belongs to the anterior ethmoid. This space is bounded medially by the uncinate process and the mucosa covering it. Major portion of its lateral wall is bounded by the lamina papyracea, and the frontal process of maxilla to a lesser extent. Defects in the medial wall of the infundibulum is covered with dense connective tissue and periosteum. These defects are known as anterior and posterior fontanelle. Anteriorly the ethmoidal infundibulum ends blindly in an acute angle.

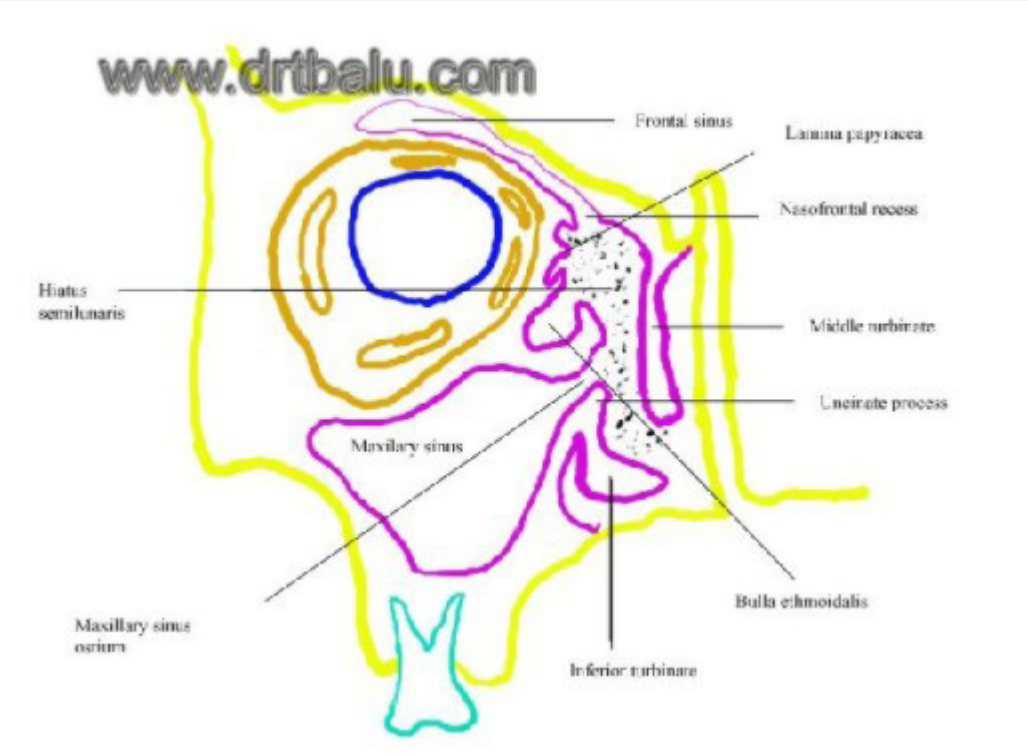

Image showing osteomeatal complex

Hiatus semilunaris:

Lies between the anterior wall of the Bulla and the free posterior margin of the uncinate process. This is infact a two dimensional space. Through this hiatus a cleft like space can be entered. This is known as the ethmoidal infundibulum. This ethmoidal infundibulum is bounded medially along its entire length by the uncinate process and its lining mucosa. The lateral wall is formed by the lamina papyracea of the orbit, with participation from the frontal process of the maxilla and the lacrimal bone. The anterior group of sinuses drain into this area. Infact this area acts as a cess pool for all the secretions from the anterior group of sinuses.

Osteomeatal complex:

This term is used by the surgeon to indicate the area bounded by the middle turbinate medially, the lamina papyracea laterally, and the basal lamella superiorly and posteriorly. The inferior and anterior borders of the osteomeatal complex are open. The contents of this space are the agger-nasi, nasofrontal recess (frontal recess), infundibulum, bulla ethmoidalis and the anterior group of ethmoidal air cells.

Some authors divide this osteomeatal complex into anterior and posterior. The classic osteomeatal complex described already has been described as the anterior osteomeatal complex, while the space behind the basal lamella containing the posterior ethmoidal cells is referred to as the posterior ethmoidal complex, thus recognizing the importance of basal lamella as an anatomical landmark to the posterior ethmoidal system. Hence the anterior and the posterior osteomeatal complex has separate drainage systems. So when the disease is limited to the anterior compartment of the osteomeatal complex, the ethmoid cells can be opened and diseased tissue removed as far as the basal lamella, leaving the basal lamella undisturbed minimizing the risk during surgery.

Ethmoid air cells:

Ethmoid sinus consists of 7-15 cells with a variable pneumatization pattern. The Ethmoid bulla is the most consistent landmark forming the most anterior ethmoidal air cell. The lateral extent of the bulla is formed by the lamina papyracea. The basal lamella or the horizontal portion of the middle turbinate separates anterior from the posterior ethmoidal cells. Anterior ethmoidal cells drain into the middle meatus while the posterior ethmoid and sphenoid sinus drain into the sphenoethmoidal recess.

The anterior ethmoid cells are an important part of osteomeatal unit. Obstruction in this area can affect frontal and maxillary sinus drainage. Cells that migrate from ethmoid cell development include:

Frontal cells

Supraorbital cells

Infraorbital cells (Haller cell)

Sphenoethmoidal cells (onodi cells)

Suprabullar recess is a potential air space that can exist between the ethmoid bulla and skull base.

Agger Nasi:

This is the anterior most of all ethmoidal air cells. The term Agger in Latin means Mound/Eminence. Endoscopically this cell is visualised as a prominence anterior to the insertion of middle turbinate. Rarely this pneumatization can involve the antero superior portion of unicinate process.

Embryologically this cell is a pneumatization of superior remnant of first ethmoturbinal whorl present in the lateral wall of nasal cavity. Identification of agger nasi holds the key to access to frontal recess area. Pneumatization of agger nasi can have an impact on uncinate process insertion and patency of frontal recess area.

Maxillary sinus: (Also known as antrum of Highmore)

These paired sinuses lie under the cheek. It is the largest of the group of para nasal sinuses. The capacity of the maxillary sinus is roughly 1 fluid ounce (30ml). It is more or less shaped like a pyramid.

Base (medial wall): The base of the pyramid corresponds to the lateral nasal wall. This wall has its convexity facing the sinus. The central portion of the base is very thin, and in some areas could even be membranous. The natural ostium of this sinus is present in this wall. It is present more towards the roof of the sinus cavity than its base.

Anterior: Wall corresponds to the facial surface of the superior maxilla. Over the canine fossa it is only 2mm in thickness. It is though this canine fossa area that maxillay antrum is entered during Caldwell Luc surgery.

Boundaries of Canine fossa:

Inferior: Bounded by the alveolar ridge

Laterally: Bounded by the canine eminence which is caused by the canine tooth.

Superior: Infra orbital foramen

Medial: Pyriform aperture

Posterior wall: of maxillary sinus is also known as temporal surface. It is very thick and is formed by the body of the superior portion of the maxilla.

Roof: of the sinus is formed by its thin orbital wall which is traversed by the infra orbital foramen containing the infra orbital vessels and nerves. This wall is very fragile and any disease process involving the maxilla is likely to affect the orbit through this wall. This wall is further thinned out where the infra orbital canal is present.

Floor: is formed alveolar process of the maxilla and the hard palate. The roots of the first and second molar reach up to the floor of the maxillary sinus. In children the floor lies at the same level as that of the nasal cavity. In adults it lies 5 - 10 mm below the nasal cavity. It is just separated from the floor of the sinus by a thin lamella of bone. This lamella may be dehiscent commonly. Dental infections involving the 1st and 2nd molars may involve the maxillary sinus through this thin lamella of bone.

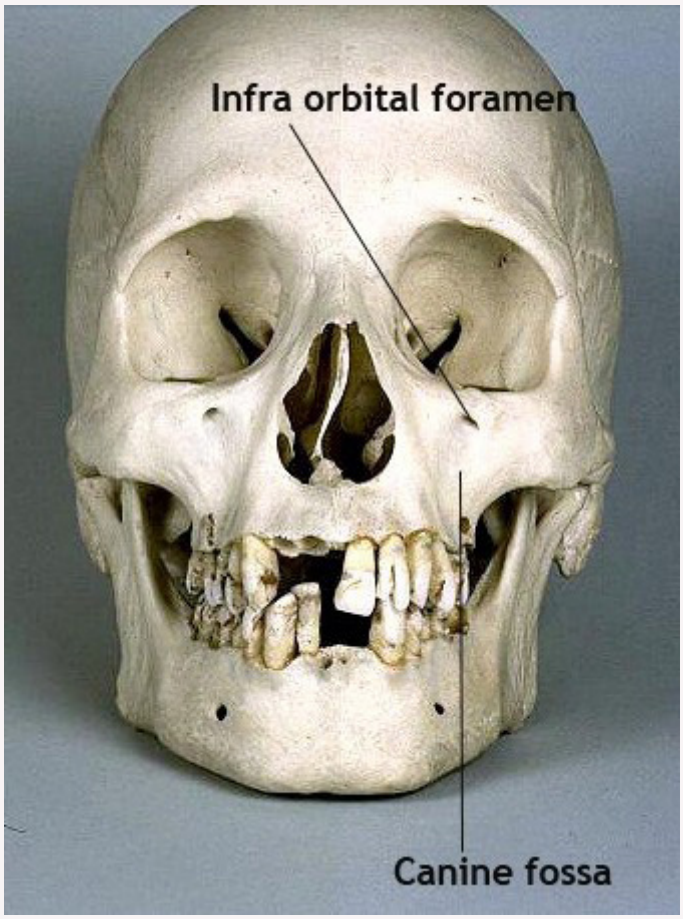

Image of skull showing infraorbital foramen and canine fossa

The maxillary sinus has biphasic growth. The first phase of growth occur during the first 3 years of life while the second phase occur between 7 - 18 years.

Ethmoid sinus:

Is situated in the anterior skull base. It is made up of complex bony labyrinth of thin walled cells. A few ethmoid cells may be present at birth. The common infections affecting the pediatric age group occur in this sinuses. In adults 6 - 10 ethmoid cells may be present.

Boundaries:

Lateral wall: is formed by the orbital plate of the ethmoid otherwise known as the lamina papyracea. This is a thin lamina of bone separating the orbit from the ethmoidal air cells. This wall could be

dehiscent (normal variant). Infections involving the ethmoid air cells may spread to the orbit through this wall.

Roof: is formed by the frontal bone anteriorly and by the face of sphenoid and orbital process of palatine bone posteriorly. The ethmoidal cells increase in size from above downwards, and from before backwards.
The cells of the ethmoid sinus are divided into two groups, the anterior and posterior group. The anterior ethmoidal cells drain into the infundibulum of the middle meatus while the posterior ethmoid cells drain into the superior meatus. The anatomy of the ethmoidal cells are highly variable, sometimes the middle turbinate may contain an air cell known as the concha bullosa. An enlarged concha bullosa may impede drainage from the middle meatus. Another common anatomical variation is the presence of agger nasi air cell. This is a large ethmoidal air cell present just anterior to the antero superior attachment of the middle turbinate. Since these cells lie in close proximity to the frontal recess area, they could impede ventilation and drainage of the frontal sinus. These agger nasi cells are commonly involved in the pathogenesis of the formation of frontal mucocele.

Obstruction to the frontal sinus drainage by the presence of a large agger nasi cell may cause secretions within the frontal sinus to be dammed inside. Accumulation of mucoid secretions cause enlargement of frontal sinus. At first the frontal sinus enlarges in size by expansion of its bony walls. At a later stage bone erosion can also occur. Commonly the posterior table of the frontal sinus is eroded. The anterior table also can be eroded in rare cases.

Haller cells are ethmoidal air cells belonging to the anterior ethmoidal group. These cells are also known as the infra orbital cells. Enlargement of these cells can impede the maxillary sinus drainage. Another variation is the extension of the posterior group of ethmoidal air cells supero lateral to the sphenoid sinus. These cells are known as onodi cells. These cells lie perilously close to the optic nerve making them at risk during fess surgeries.

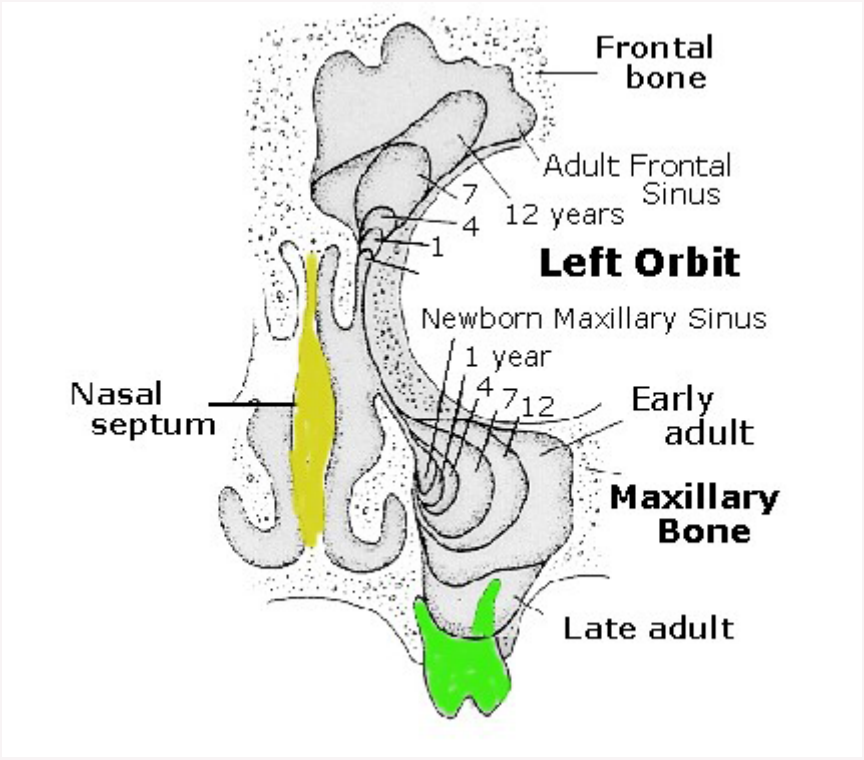

Image showing the sizes of paranasal sinuses in various age groups

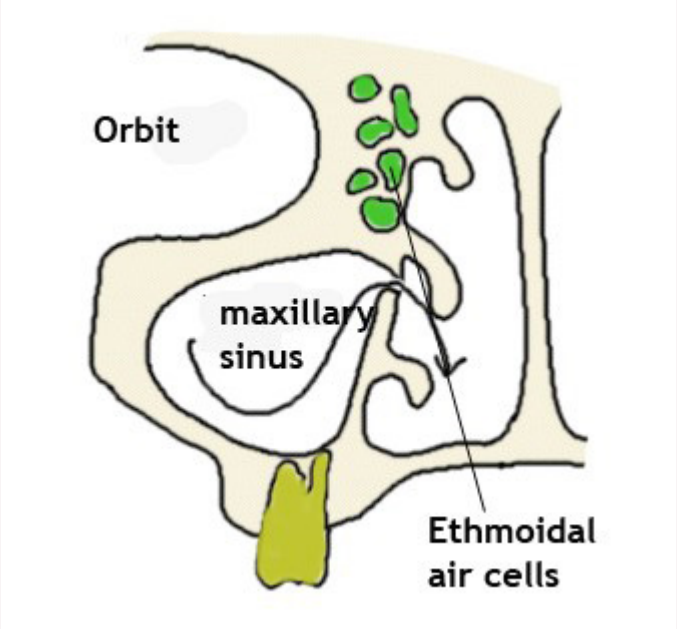

Image showing maxillary and ethmoidal air cells

Frontal sinus:

Among the para nasal sinuses this sinus shows the maximum variations. Infact variations are so immense that it can safely be stated that frontal sinuses are unique in each and every individual. It may be absent in 5 % of individuals. It is more or less shaped like a L.

Posterior wall: corresponds to the anterior wall of the anterior cranial fossa.

Floor: is formed by the upper part of the orbits.

Frontal sinus appear very late in life. Infact they are not seen in skull films before the age of 6.

The sinus drains into the anterior part of the middle meatus through the fronto nasal duct.

Frontal sinus outflow tract (frontal recess):

This is a tortuous path that leads from the frontal sinus into the nasal cavity. Bulla ethmoidalis which forms the middle ethmoid air cells commonly defines the dimensions and limits the posterior aspect

of the frontal sinus outflow tract. Anteriorly the frontal sinus outflow tract is bordered by agger nasi cells and in some cases the uncinate process. The lateral wall of frontal recess is bounded by the lamina papyracea. Medial boundary happens to be the middle turbinate. Posteriorly the frontal recess is bordered by the anterior wall of the ethmoid bulla. This area is commonly affected by the development of anterior ethmoid cells like the frontal or supraorbital cells. Enlargement or disease process involving any of the cells within the frontal sinus outflow tract may contribute to the bockage of frontal sinus.

Accessory sinuses of frontal region:

These cells constitute the frontal sinus complex.

Frontal sinus drainage region is the most variable portion of the whole of the nasal cavity. These variations can lead to obstruction to the frontal sinus outflow tract causing frontal sinusitis.

Attempts have been made to classify the variations of these cells abutting this vital area. Going by their drainage channels these cells are generally believed to be ethmoidal in origin.

Synonyms: Air cells abutting the frontal sinus have been given various names. They include: Frontal cells, frontal bullae, Supernumerary frontal sinuses, supraorbital sinuses and supraorbital cells.

Why these cells are important ?

These cells can impinge on the frontal sinus and frontal recess area causing obstruction. These cells can also be mistaken for frontal sinus itself during endoscopic surgery. Failure to address these cells could lead to persistence of frontal sinus disease.

Accessory cells in the frontal region can be classified under three categories:

1. Frontal cells

2. Supraorbital cells

3. Intersinus septal cells

Frontal cells: are ethmoidal cells that have pneumatized into the frontal bone.

Van Alyea classified these cells into two groups:

1. Cells that occupy the area of frontal recess

2. Cells that have managed to invade the frontal sinus cavity. These cells have been described in three different locations: 1. the floor of the frontal sinus, 2. Medial wall of frontal sinus, 3. posterior wall of frontal sinus.

According to Van Alyea supra orbital and intersinus septal cells are invading cells.

Bent's classification of accessory frontal cells:

The classification proposed by Bent grouped these cells into four different types based on their loca-

tion.

Type I: This type represents a single frontal cell just above the agger nasi cell

Type II: This type consists of a tier of two or more air cells superior to the agger nasi cell.

Type III: This type has a single frontal cell which is massive and it pneumatizes superiorly into the frontal sinus

Type IV: These cells are contained entirely within the frontal sinus, thus giving it a cell inside a cell appearance.

Among these types, types III and IV are considered to be invasive types.

Supraorbital cells: These cell pneumatize the orbital plate of the frontal bone posterior to the frontal recess and lateral to the frontal sinus. These cells appear to extend over the orbit, appearing as the lateral cell in a coronal CT scan. Endoscopically these cells appear as separate ostia present along the anterolateral aspect of the roof of the ethmoid. These cells lie postero lateral to the frontal sinus ostia and anterior to the anterior ethmoidal artery.

Intersinus septal cell: is a midline cell that pneumatizes the frontal bone between the two frontal sinuses.

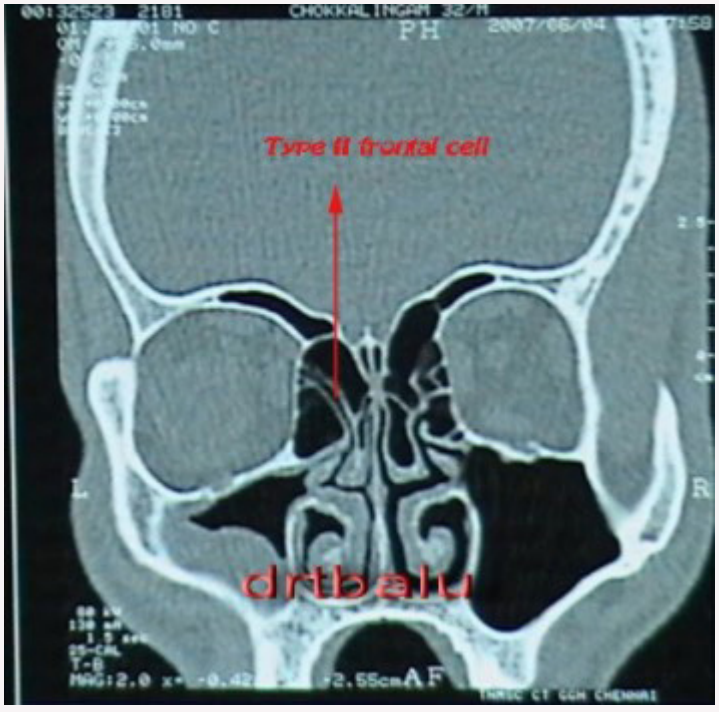

Image showing TYPE II frontal cell as demonstrated in a coronal CT scan

Sphenoid sinus:

Is located in the skull base at the junction of the anterior and middle cranial fossa. Pneumatization of sphenoid starts during the 4th year of childhood and gets completed by the 17th year. The sphenoid sinuses vary in size and may be asymmetric.

They drain through the superior meatus via a small ostium about 4mm in diameter located disadvantageously 20mm above the sinus floor.

This sinus is related to several important vital structures. They are:

1. Pituitary gland lies above the sphenoid sinus.

2. Optic nerve and internal carotid arteries traverse its lateral wall.

3. The nerve of pterygoid canal lie in the floor of the sinus.

Hence infections of sphenoid sinus may involve the optic nerve if the canal of the optic nerve is dehiscent.

Sphenoid sinus can be classified based on pneumatization into conchal, presellar, sellar and postsellar.

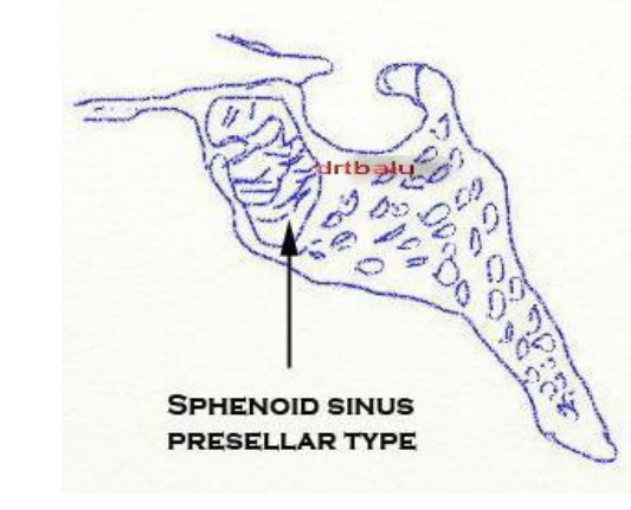

Image showing presellar type pneumatization of sphenoid sinus

Conchal type:

In this type the area below the sella is a solid block of bone without an air cavity. This type is common in children under the age of 12 because pneumatization begins only after the age of 12.

Sellar type:

In this type the air cavity extends into the body of the sphenoid below the sella and may extend as far posteriorly as the clivus. This type is commonly seen in 85% of individuals.

In well pneumatized sphenoid sinus, the pterygoid canal and a segment of maxillary division of trigeminal nerve could be identified in the lateral recess of the sphenoid sinus.

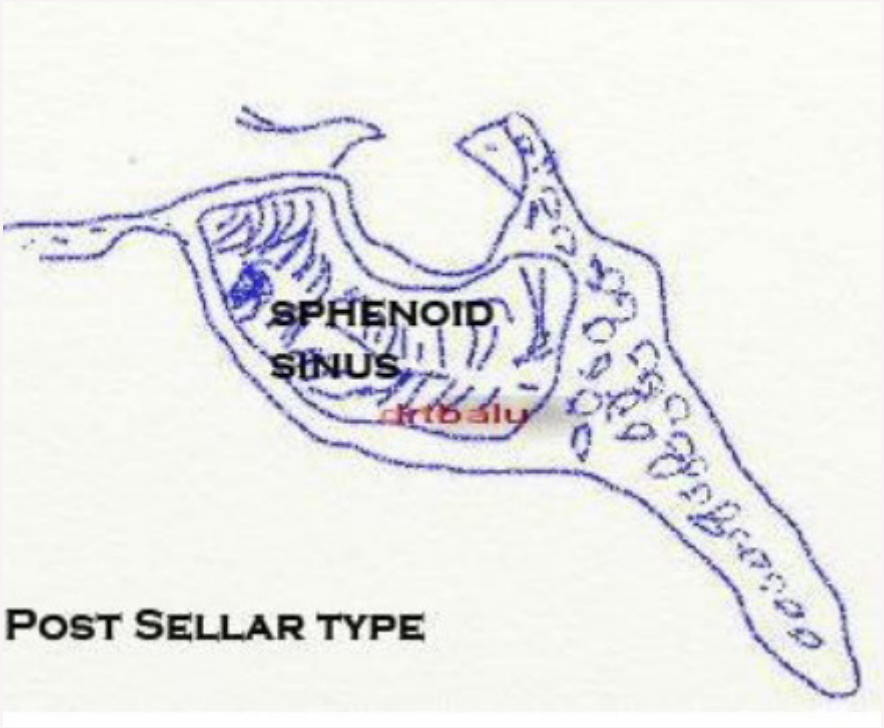

Image showing post sella type of sphenoid pneumatization

The roof of the sphenoid (planum sphenoidale) anteriorly is continuous with the roof of ethmoidal sinus. At the junction of the roof and posterior wall of sphenoid the bone is thickened to form the tuberculum sella. Inferior to the tuberculum sella on the posterior wall is the sella turcica. It forms a bulge in the midline. The bone over the sella could be 0.5 – 1 mm thick. This may get thinner inferiorly. It is hence easy to breech the sella in this tinnest part. This area can be easily identified by a bluish tinge of the dura which is visible through the thin bony covering.

Possible variations of intersinus septum are as follows:

1. A single midline intersinus septum extending on to the anterior wall of sella.
2. Multiple incomplete septae may be seen
3. Accessory septa may be present. These could be seen terminating on to the carotid canal or optic nerve.

Lateral wall of sphenoid sinus: is related to the cavernous sinus. This sinus is formed by splitting of the dura. It extends from the orbital apex to the posterior clinoid process. Cavernous sinus contains very delicate venous channels, cavernous part of internal carotid artery, 3rd, 4th and 6th cranial nerves. It also contains some amount of fatty tissue.

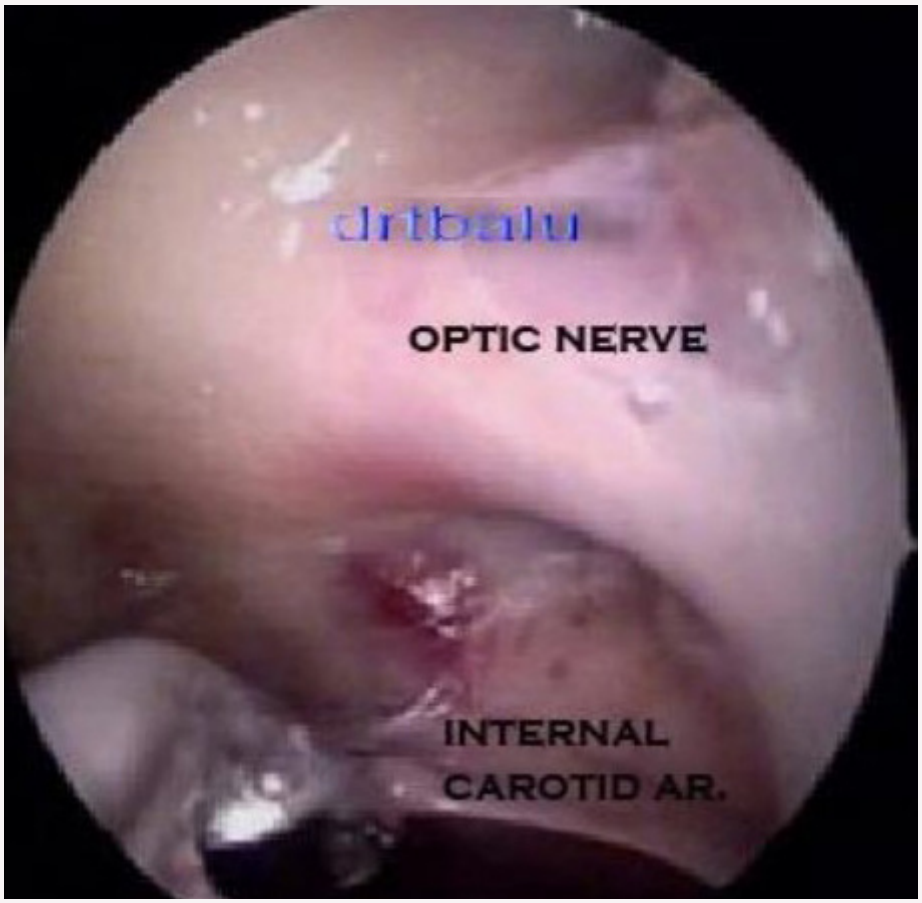

Image showing the interior of sphenoid sinus

The prominence of internal carotid artery is the postero lateral aspect of the lateral wall of sphenoid sinus. This prominence can be well identified in pneumatized sphenoid bones. On the antero superior aspect of the lateral wall of sphenoid sinus is seen the bulge formed by the underlying optic nerve.

These two prominences are separated by a small dimple known as the opticocarotid recess. The optic nerve and internal carotid artery is separated from the sphenoid sinus by a very thin piece of bone. Bone dehiscence is also common in this area.

Onodi Cell:

This cell is also known as sphenoethmoidal cell. This cell is christened after Adolf Onodi of Budapest who studied the relationship of ethmoid air cells in relation to optic nerve. These cells belong to posterior ethmoid group. Onodi cells extend superiorly and laterally to the sphenoid sinus. Its pneumatization can reach up to the clinoid process. This cell is related to optic nerve in its lateral wall.

If this cell is large carotid artery could be seen bulging from its posterior wall. Any attempt to open the sphenoid sinus through this cell is fraught with dangerous complications like injury to optic nerve / internal carotid artery. Pre op CT scan is the best way to identify this condition. "Forewarned is forearmed".

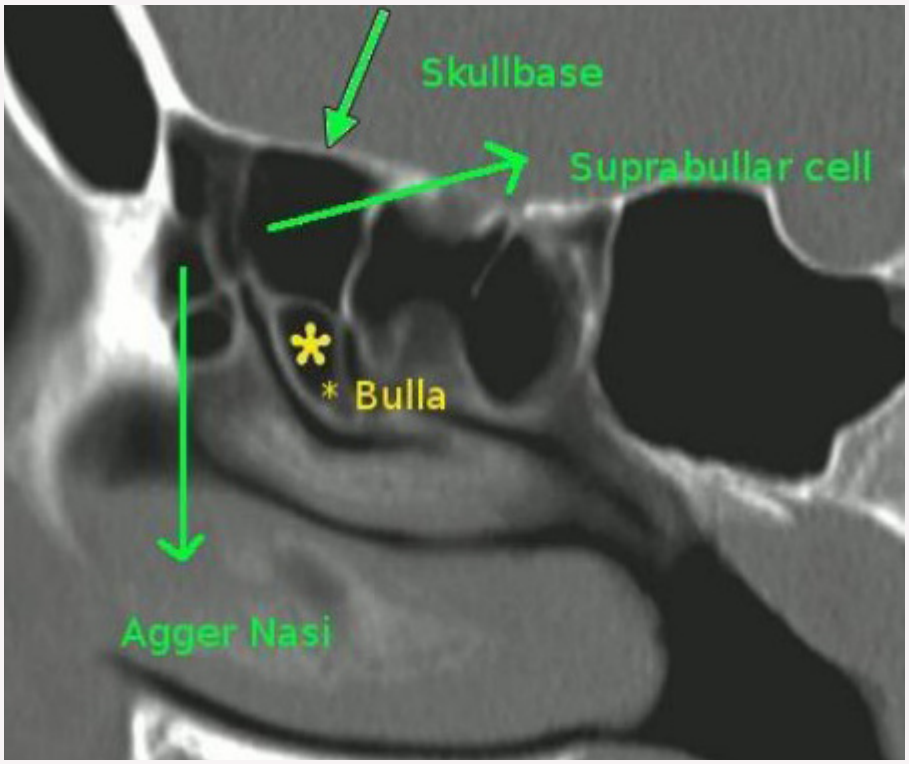

Image showing Sagittal view of CT nose and pns showing large agger nasi cell and supra bullar cell. Note frontal recess is bounded anteriorly by agger nasi cell and posteriorly by suprabullar air cell.

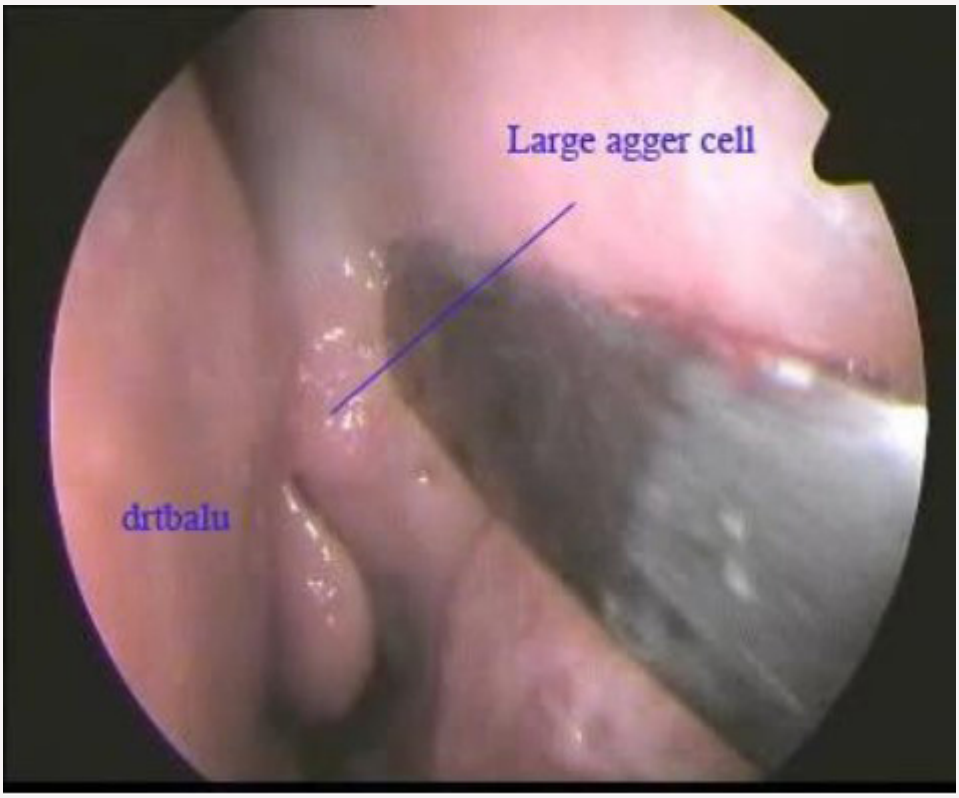

Image showing endoscopic view of a large agger nasi cell

Drainage System of Paranasal sinuses

Introduction:

Study of drainage system of paranasal sinuses is important in the present day context of Functional endoscopic surgery and Balloon dilatation techniques in managing sinus infections and ostial obstruction. These minimally invasive tools have thrown further light into the drainage pattern of various paranasal sinuses.

The following are the documented various racial variations:

1. The volume of maxillary sinus varies between races and sexes.

2. White population has a higher incidence of concha bullosa of middle turbinate and paradoxical bending of middle turbinate when compared to that of other races.

3. Infra orbital / suprabullar cells are commonly seen in white races.

4. Sphenoethmoidal cells are commonly seen in Chinese.

5. Bent uncinate process and complete absence of sinuses are common in Chinese.

Studies have revealed extensive intercommunication between various paranasal sinuses. It can be safely construed that all paranasal sinuses in addition to their major drainage channel also contains openings connecting one with the other.

Development of nose and paranasal sinuses:

Study of embryology of nose and paranasal sinuses will go a long way in enhancing our understanding of the drainage patterns of various paranasal sinuses. The whole nasal cavity and adjoining paranasal sinuses develop from a cartilagenous analge called the nasal capsule. This nasal capsule appears between the 7th and 8th weeks of embryonal life. The first area where this cartilage begins to develop is in the nasal septal area. The lateral nasal wall develops much later. The following are the chronology of development of lateral nasal wall:

1. The cartilage of inferior turbinate develops during the 8th week of gestation.
2. Middle turbinate begins its development during the 9th week of gestation.
3. Superior turbinate begins to develop during the 12th week of gestation.
4. Uncinate begins to develop during the 9th week.
5. Ethmoidal bulla begins its development during 12th week.
6. Anterior ethmoidal cells starts their development during 22nd week
7. Posterior ethmoid cells begin their development during 40th week

The nasal capsule has tight connections to its surroundings, especially to the cartilagenous analge of body and minor ala of sphenoid bone. This factor helps in the normal development of sphenoid bone thus ensuring normal development of sphenoid sinus.

Expansion of mucous membrane forms the paranasal sinuses. The first air filled sacs in the ethmoid bone begins from the bulla ethmoidalis area. Bulla ethmoidalis gives rise to anterior and middle ethmoid air cells. Ventral to anterior ethmoidal cells the developing primordial ethmoidal infundibulum extends infero laterally towards the inferiorly placed precursor of maxillary bone. This forms the primordial maxillary sinus. At birth only the ethmoid and rudimentary maxillary sinus are present. The frontal and sphenoid sinus develops after birth due to gradual pneumatization of frontal and sphenoid bones respectively.

During the process of pneumatization mucous membranes encounter each other. When this happens the underlying mesenchymal layer may disappear causing intersinus communications to form. Eventhough these channels of communication plays very little role in ventilation and drainage of sinuses infections can spread to other sinuses via these channels.

Drainage pathways of paranasal sinuses:

Frontal sinus: May show three types of drainage patterns.

1. Direct drainage via frontal recess
2. Drainage via ethmoido nasal route
3. Drainage via ethmoido maxillary route

Multiple drainage patterns are commonly seen in frontal sinus. Direct drainage is seen only in a fraction of patients. If the frontal sinus drains directly via frontal recess presence of anterior ethmoidal cells can cause obstruction to drainage of frontal sinus leading on to frontal sinus infection.

Ethmoidal cells:

These cells drain directly via upper / middle meatus.

These cells may share common drainage channel with maxillary sinus

These cells may drain via maxillary sinus

Sphenoid sinus:

Drains directly into the nasal cavity.

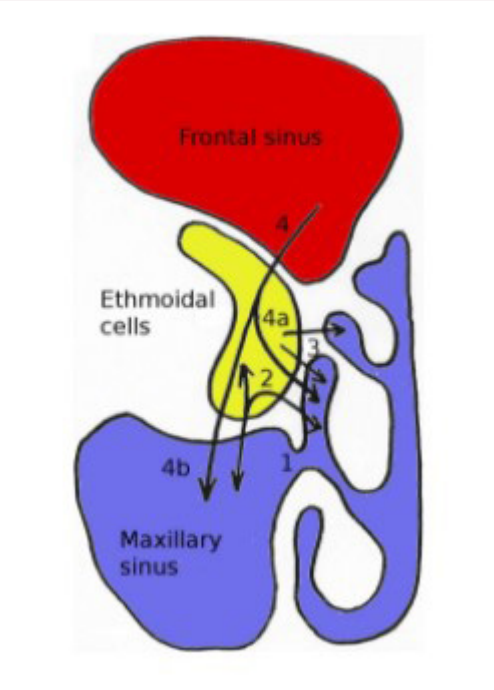

Image showing Coronal view showing various drainage patterns

1. Natural ostium / accessory ostium of maxillary sinus
2. Maxilloethmoid nasal route
3. Nasal ostia of ethmoidal sinus
4a. Ethmoideo-nasal route
4b. Ethmoideo-maxillary route

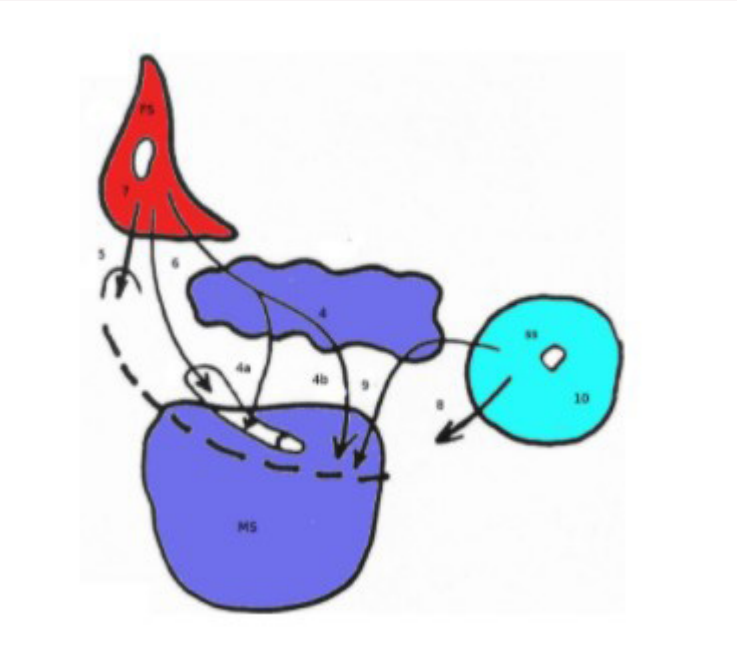

Image Sagittal view showing the drainage patterns of paranasal sinuses

Fs – Frontal sinus

Ms- maxillary sinus

Ss- Sphenoid sinus

The following points should be borne in mind before performing Balloon sinuplasty / FESS procedures for chronic sinus infections:

1. Accessory sinus ostia exist for each paranasal sinuses

2. Many sinuses do not drain directly into the nasal cavity but indirectly drains via adjacent sinuses. For example sphenoid sinus drains both via posterior ethmoidal cells and directly into the nasopharynx.

3. Major drainage pathway of frontal sinus is over the ethmoidal sinus, via the ethmoids into the maxillary sinus and then into the nasal cavity.

4. These pathways are not normally accessible during normally performed endonasal surgeries. Inadvertant manipulation can cause fractures of thin septa between these sinuses thereby impairing normal

drainage patterns.

5. Presence of secondary / accessory ostia is a definite sign of chronic sinus infection.

6. Presence of accessory / secondary ostia ensures recirculation of mucous due to mucociliary mechanism which tends to beat towards the natural ostium.

7. If accessory ostium is present Balloon sinuplasty invariable ends up dilating the accessory ostium instead of natural one.

It makes real sense if these drainage patterns could somehow be ascertained prior to surgical procedure instead of performing blind dilatation.

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Factors affecting drainage of paranasal sinuses:

1. Deviated nasal septum obstructing the infundibulum

2. Involvement of drainage pathway of the anterior group of sinuses

3. Large agger nasi air cell could impinge on the frontal drainage pathway

4. A large / infected infraorbital air cell could impinge on the middle meatus drainage pathway lead-

ing to obstruction of maxillary sinus. Obstruction to sinus drainage usually starts from the anterior ethmoidal sinus before proceeding posterior.

Isolated inflammatory pathologies involving posterior sinuses without involvement of anterior group of sinuses is rather uncommon.

CT scan is useful in identifying the exact location of obstruction which would be helpful for the surgeon to address during surgery. Anatomical anomalies which lead to obstruction to the drainage of the paranasal sinuses should be addressed by the surgeon during surgery.

Indications for CT scan Paranasal sinuses

CT scanning can be very helpful in the diagnosis of acute and chronic sinusitis, neoplastic and inflammatory processes and other problems like congenital anomalies.

Acute sinusitis is caused by bacterial / fungal infections usually secondary to an obstructed sinus cavity.

Structural anatomic variations which cause obstruction to sinus drainage channels causing sinusitis can be revealed in CT images.

Acute oedema of sinonasal mucosa in response to infection / allergens and compromise of nasociliary flow can all contribute to acute and chronic sinusitis. The same may be revealed in CT images.

CT findings of acute sinusitis include:

1. Opacification of sinuses

2. Presence of air fluid levels

3. Thickened sinus mucosa

Non-specific CT findings which could be associated with many sinonasal conditions include:

1. Thickened turbinates

2. Diffusely thickened sinus mucosa

These features can clearly be identified in CT images.

In chronic sinusitis, repeated episodes of acute sinusitis, or smoldering infection is combined with unfavorable anatomic factors lead to vicious cycle of infection, mucociliary incompetence and chronic mucosal inflammation.

CT findings suggestive of chronic sinusitis include:

1. Mucosal thickening

2. Opacified air cells

3. Evidence of bone remodeling

4. Bony thickening due to inflammatory osteitis

5. Bony erosion could occur in severe cases, especially if associated with massive polypi or mucoceles.

Presence of bony destruction in CT should alert the surgeon to consider other less common diseases like sinonasal tumors or granulomatous disease processes.

Sinonasal polyp can create sinus disease by obstructing the sinus drainage obstruction or mass effect by causing secondary infections. Sinonasal polyp appear on CT scans as nodular or rounded masses and amorphous opacified blobs of tissue. Bony remodeling can occur, it is typically subtle which is expected from the usual slow growth pattern of sinonasal polypi and other benign nasal disorders in general.

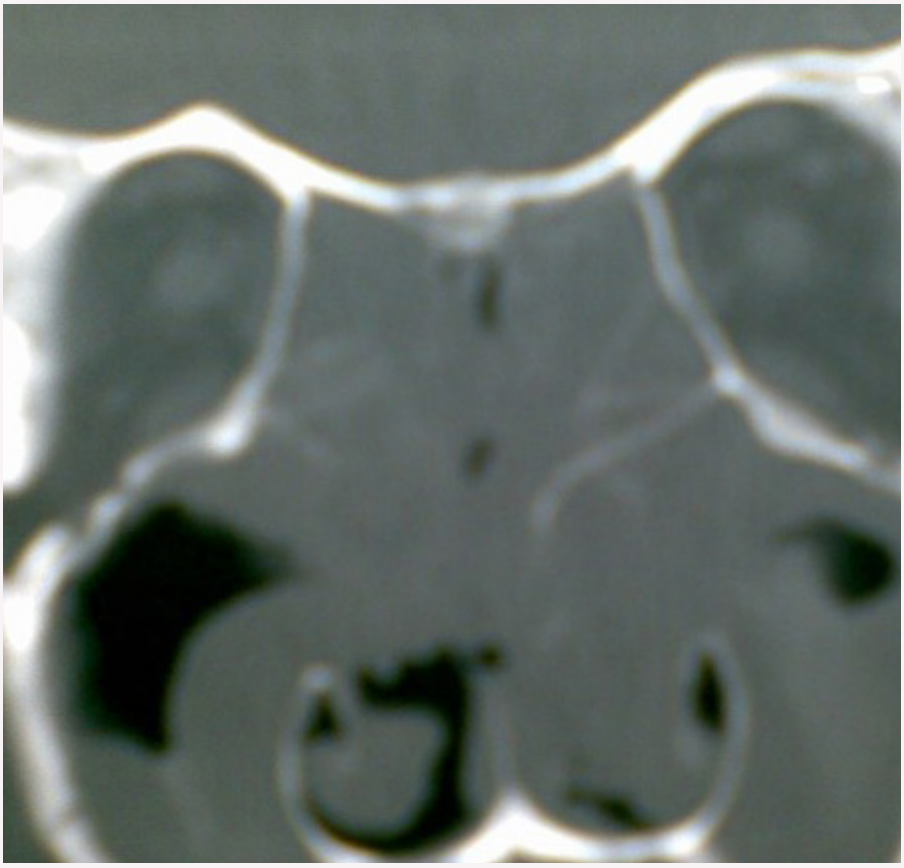


Image showing coronal CT of a patient with bilateral ethmoidal polypi

Fungal sinusitis can be diagnosed with reasonable accuracy from CT images. It can be divided into invasive fungal sinusitis, chronic noninvasive fungal sinusitis and allergic fungal sinusitis. Invasive fungal sinusitis due to mucormycosis or aspergillosis is seen in immunocompromised patients and can have a fulminant course. Early in the disease process, opacifiation of sinuses is seen. Progression of disease is more fulminant in invasive fungal sinusitis. CT findings mirror these changes with expanding localized destruction of bone.

Experienced clinicians can accurately correlate the anatomic and clinical realities of a particular patient. Sinus CT scans must be read with a systematic approach. Preliminary CT images should be surveyed and it should include:

Name of the patient

Indications for CT scan

Type of CT scan

Cross sectional view (type)

Visualization of potential bottle neck areas that could be occluded by disease states and anatomical variations.

Systemic approach would be helpful when interpreting CT images. In coronal views the scan should be read from anterior to posterior and from top to bottom on axial sections.

CT scan images can be used as a road map by the surgeon while performing FESS. A number of additional anatomic and structural features can be studied, which include the thickness, orientation, and the most medial bowing of lamina papyracea must be noted. Any dehiscences or excessive medial bowing of this thin bone should be noted prior to surgery. The depth of the olfactory fossa should also be assessed. The relationship of the sphenoid sinus and posterior ethmoid cells vis a vis the internal carotid artery and optic nerves should be noted.

Important radiological landmarks that should be noted in CT images:

CT images can reveal the following anatomical landmarks:

Landmarks clearly seen in coronal CT of nose and sinuses:

1. Relationship of cells within the frontal recess and their relationship to the frontal sinus.

2. Depth of olfactory fossa: The deeper the fossa (increased distance from cribriform plate and fovea ethmoidalis) the higher the chance for fracture or perforation with surgical maneuvers.

3. Slope, thickness, and asymmetries in the height of the ethmoid roof:

The prevalence of intracranial penetration during FESS is higher when this anatomic variation occurs.

Intracranial penetration is more likely to occur on the side with the lower roof.

4. Patency of the osteomeatal complex

5. Attachment of the middle turbinate

6. Width of the infundibulum

7. Vertical distance from the maxillary sinus to the ethmoid roof in the posterior ethmoid cells.

8. Degree of pneumatization of the maxillary sinus

9. Status of lamina papyracea

    Dehiscence in the lamina papyracea

    Shape of the medial orbital wall

10. Attachment of the uncinate process

11. Alignment of nasal septum

12. Size and status of the maxillary sinus (hypoplastic / normal size)

13. Other variations, like the presence of concha bullosa

Landmarks seen on axial sections:

1. Depth and ratio of anterior and posterior ethmoid cells compared to that of sphenoid sinus

2. Degree of pneumatization of sphenoid sinus

3. Position of sphenoid intersinus septae

4. Presence of absence of Onodi cell

5. Dehiscence of bony covering of the carotid artery or optic nerve.

    Relationship of the optic nerve to the posterior ethmoid cells.

    The presence of anterior clinoid process pneumatization

6. Degree of indentation created by the carotid artery and optic nerve.

7. Position of the uncinate (medial vs lateral)

8. Patency of the osteomeatal complex

9. Patency of the V-shaped ethmoidal infundibulum

10. Alignment of the nasal septum

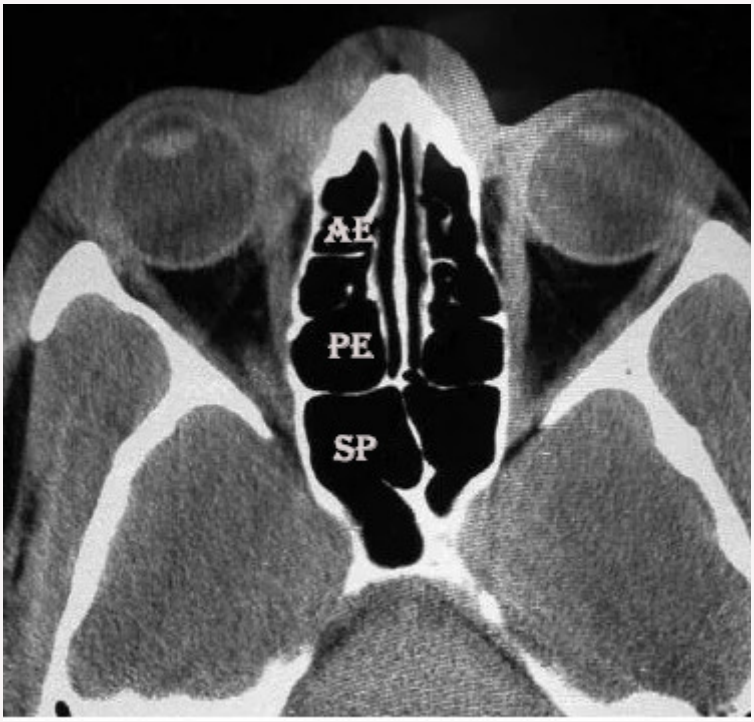
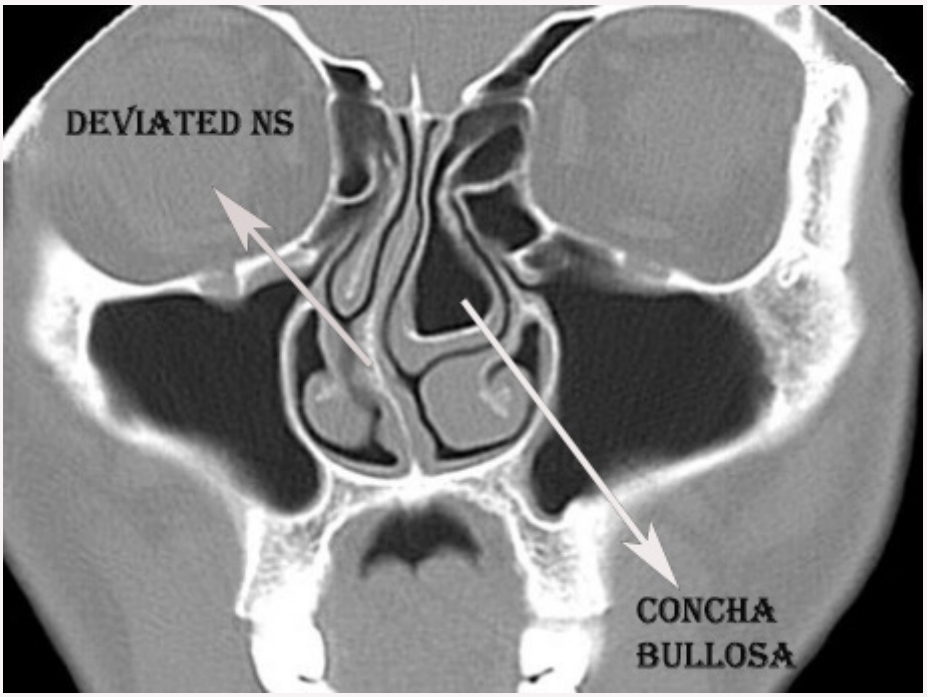


Image showing anterior (ae) and posterior ethmoid air cells (pe). Sphenoid sinus (sp) with intersinus septum.



Coronal CT of nose and sinuses showing deviated nasal septum to the right and concha bullosa on the left side (pneumatized middle turbinate)

Performing Endoscopic sinus surgery without performing CT scan of nose and sinuses particularly coronal views will become a problem for the surgeon and wold invite ligations in case of complications following surgery. Routine CT imaging will ensure that the operating surgeon is aware of anatomical variations inside the nasal cavity and the presence / absence of various ethmoidal cells. It also allows the surgeon to assess the level of anterior skull base ensuring that it is not breached inadvertantly.

CT scan coronal cuts 1 mm is needed when image guidance surgery is performed. Image guidance system uses a computer, specialized software and an electromagnetic tracking system to help the surgeon perform nasal endoscopic sinus surgical procedures as precisely as possible. Surgeon will be seeing the location of the instrument in real time during the procedure.

The software within the computer builds a computerized model of patient's skull anatomy using stored CT coronal images of the patient (taken with 1 mm cuts and less settings). This model acts as a three dimensional road map for the surgeon. The tracking system links the surgical instruments that will be used during surgery to the computer. These instruments will appear on the computer

display screen as a set of cross hairs which move through the computerized model of the skull. This will ensure that the surgeon can see the location of the surgical instruments in direct relation to areas of the skull anatomy that cannot be seen through the endoscope.

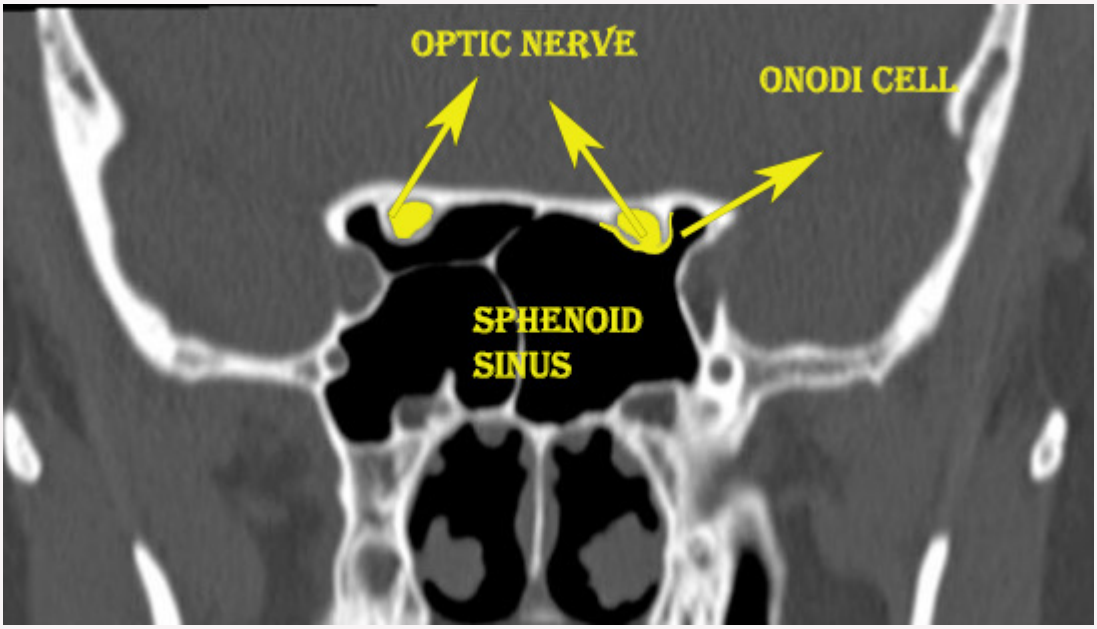


Image showing Onodi cell in relation to optic nerve and sphenoid sinus. Presence of this posterior ethmoid cell puts the optic nerve in jeopardy during surgery. Surgeon should be aware of the presence of this cell in order to prevent injury to optic nerve during the surgical procedure. The above image is coronal CT view of nose and sinus.

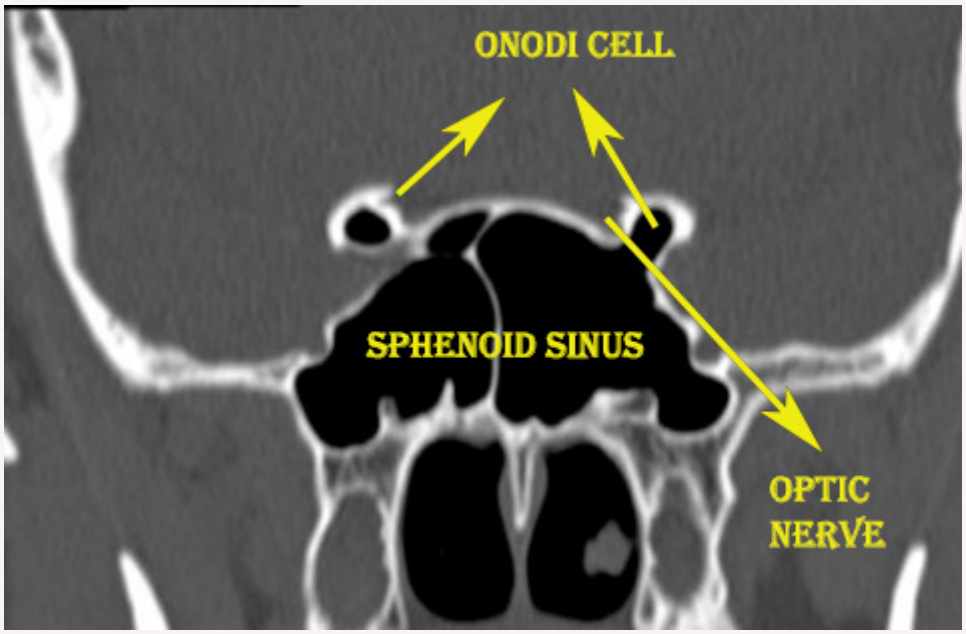


Image showing coronal CT nose and sinuses posterior cut showing onodi cell and its relationship with sphenoid sinus and optic nerve

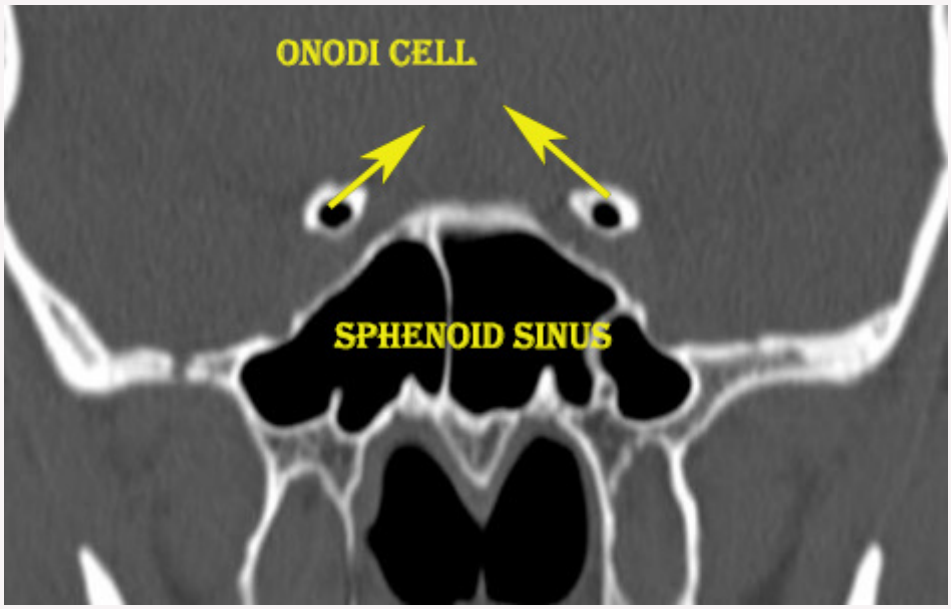


Image showing coronal CT of nose and sinuses posterior cut showing the onodi cell resembling eyes of Owl. Its relationship to the sphenoid sinus at this level should be noted.

There are three types of olfactory fossa as per Keros classification:

Keros type I - 1-3 mm deep in which the lateral lamella is short, and the ethmoid roof and cribriform plate are almost in the same plane.

Keros type II - this is the most common type. 4-7 mm deep, and the lateral lamella is longer

Keros type III - 8-16 mm deep and the ethmoid roof lies significantly above the cribriform plate.

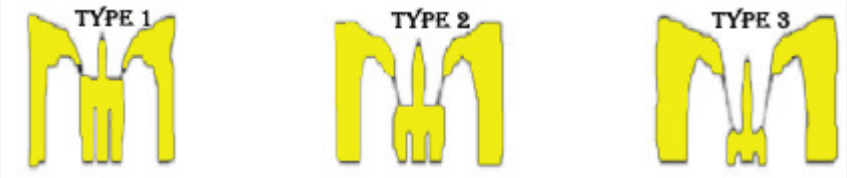


Image showing diagrammatic representation of keros types of olfactory fossa

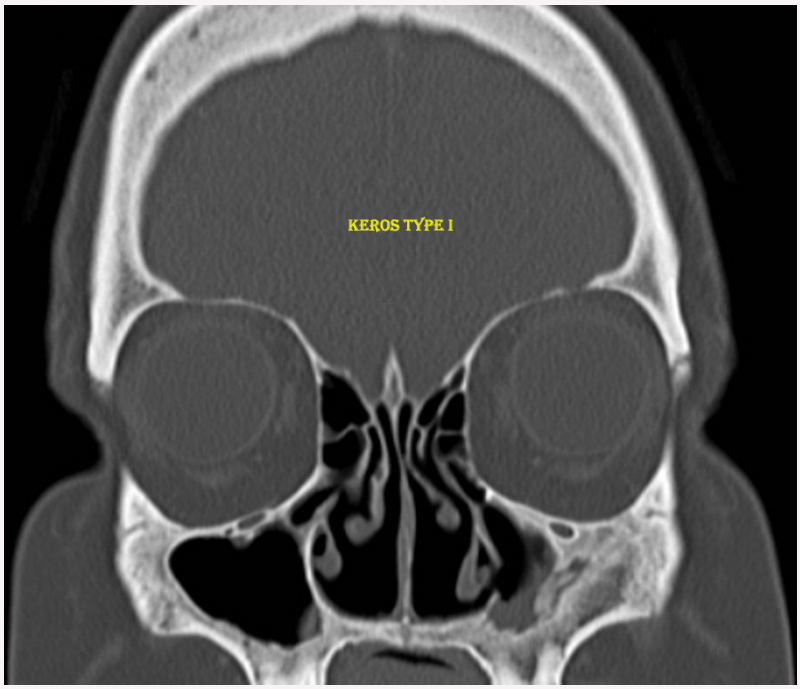


Image showing Keros Type I olfactory fossa

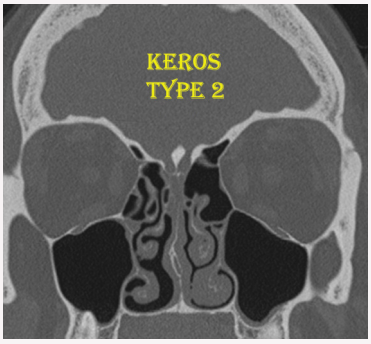


Image showing keros type 2 olfactory fossa

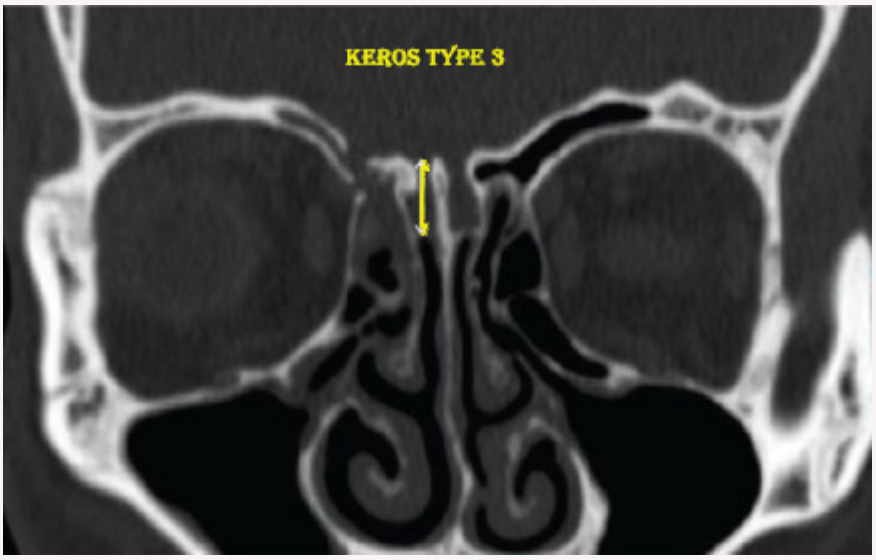


Image showing Keros type 3 olfactory fossa

Keros type 3 olfactory fossa is potentially dangerous clinical variation. Anterior skull base injury and resultant CSF rhinorrhoea is common in this variety following FESS. If the olfactory fossa is deep as in Keros type 3, the surgeon should take care not to approach medially during the surgery, as a thin bony lamella constitutes most of the roof and the frontal support is missing. In Keros type 1 surgery would be safer to perform. Good pre operative understanding of the type of olfactory fossa and its depth will help in preventing CSF rhinorrohea due to surgical breach of this area.

Superior attachment of uncinate can be assessed in coronal views. If the superior portion of the uncinate is attached to the lamina papyracea the frontal sinus outflow tract will drain medial to the infundibulum. If it is attached to the middle turbinate then frontal sinus would drain directly into the infundibulum. If it is attached to the skull base then frontal sinus would drain into the infundibulum.

Ethmoidal air cells vary greatly in their size and number. Prior knowledge about these cells will help the surgeon to navigate inside the nasal cavity by opening up these air cells. The ethmoidal air cells are closely related to critical structures like the skull base and orbit. Knowledge of the anatomy of ethmoidal air cells will help in avoiding damage to intracranial and orbital structures during endoscopic sinus surgery.

Following features should be noted while evaluating CT images of nose and sinuses:

1. Are ll sinuses present?

2. Are the sinuses clear? Are there mucosal thickening / air-fluid level?

3. Is there evidence of bone thickening / erosion?

4. Any evidence of block in the drainage of sinuses should be observed?

5. Any abnormalities outside the Nose and Sinuses area should also be observed.

[1]

Coronal CT of Nose and Sinuses Anatomy

Coronal imaging of nose and sinuses should be performed in all patients on whom endoscopic sinus surgery is being planned. If one view is preferred by the surgeon, it happens to be this view as it demonstrates the intranasal anatomy in the same order and orientation the surgeon would see on the table when endoscope is used. Bone window settings is ideally preferred because it would clearly delineate all the ethmoidal air cells. Thickness of the coronal cuts should ideally be 3 mm in the anterior cuts and 4 mm in the posterior cuts. Invariably 3 mm - 4 mm cuts would clearly demonstrate all the ethmoidal air cells. Since the anterior ethmoid cells are smaller 3 mm cuts are needed to clearly visualize all the air cells belonging to the anterior group. On the other hand posterior ethmoid cells are larger and 4-6 mm cuts would suffice to demonstrate all the air cells belonging to the posterior ethmoid group. Currently surgeons prefer 1 mm cuts and some even insist on 0.5 mm cuts also. The advantage of thin cuts is that it would demonstrate all the ethmoidal air cells (cell by cell) enabling the surgeon to have proper understanding of all the ethmoidal air cells. Bone window setting clearly demonstrates the bony partition between individual air cells.

Reading a coronal CT image is an art. It should always read from the first cut up to the last one. No cut should be skipped. Surgeon should avoid the temptation to start focussing on the pathology immediatly. All coronal CT images should be read twice. During the first attempt focus should be on the intranasal anatomy as it would help the surgeon to avoid possible pitfalls while performing FESS. Anatomical variations if any should be clearly documented. It is only during the second approach the surgeon should focus on the pathology of the lesion.

Scout film / Gantry view: Also known as scanogram, topogram or localizer.

This will be the first cut that should be viewed. It helps the surgeon in assessing:

1. The Position of the patient. Proper positioning of the patient is a must for accurate imaging. While performing Coronal CT scan of nose and sinuses the patient should be placed in prone position with the face hyperextended and the chin placed over a chin guard.

2. Window setting (Bone / soft tissue window)

3. Size of the cuts

4. Exact location of the cuts

Image showing the Gantry view / Scout view

White lines in the coronal plane shows exactly where the cuts are placed. The first cut is ideally placed over the anterior spine of maxilla and the posterior most cut will be the end of sphenoid bone. The thickness of the CT images depend on the intervening cuts between the anterior and posterior most cuts.

In the first cut the side of the face should be ascertained. It will be marked on the view. In the first cut soft tissue over the frontal bone would be clearly visible. Even though the image is taken with bone window settings the soft tissue over the frontal bone will be visible in a shade of gray. Lateral nasal cartilages are clearly visible. Cartilaginous portion of the nasal septum is also clearly visible. Arch of the nasal bone is also visible.

In CT plain bone will be visible as dense white structures. Soft tissue would be visible in various shades of gray. Fractures involving the nasal bone will distort the 'U' shaped curve formed by normal nasal bones.

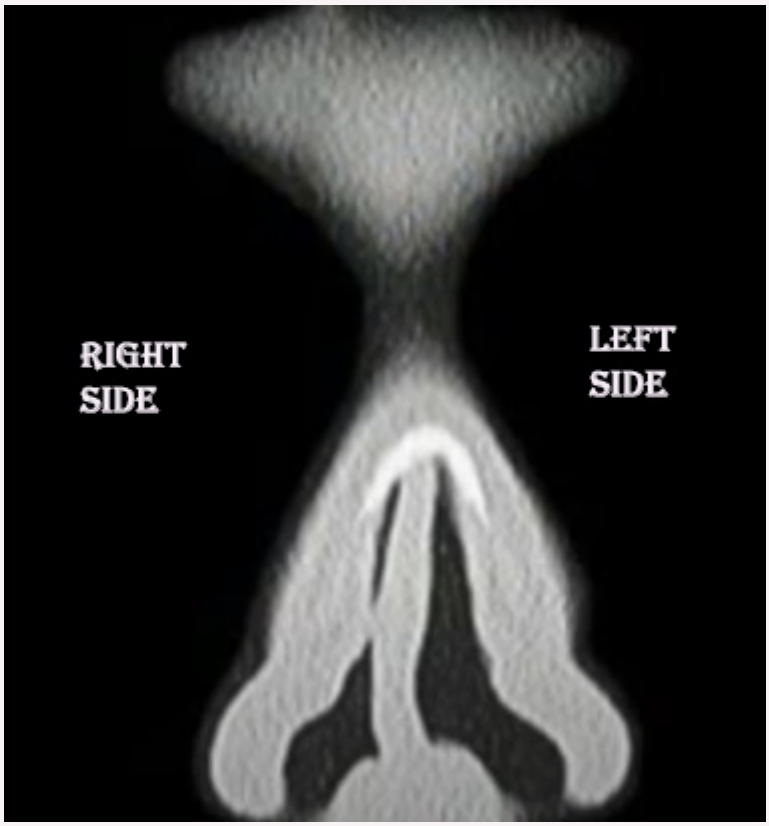


Image of coronal CT anterior most cut of nose and sinuses. Right and left sides are marked

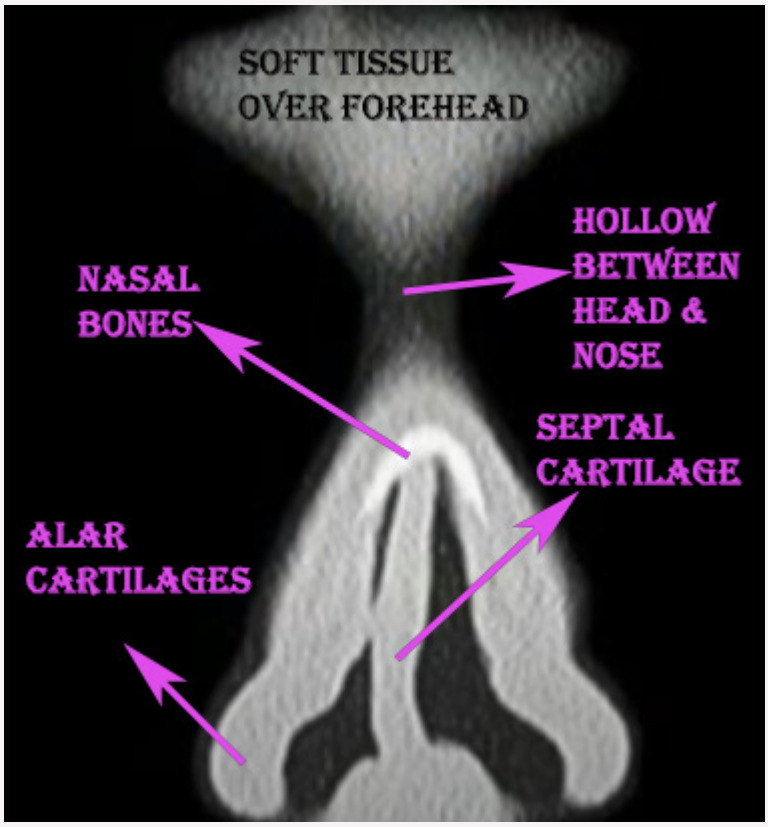


Image showing coronal CT nose and sinuses anterior most cut with the structures named. Note the anterior deviation of cartilaginous portion of nasal septum and the anterior maxillary spine.

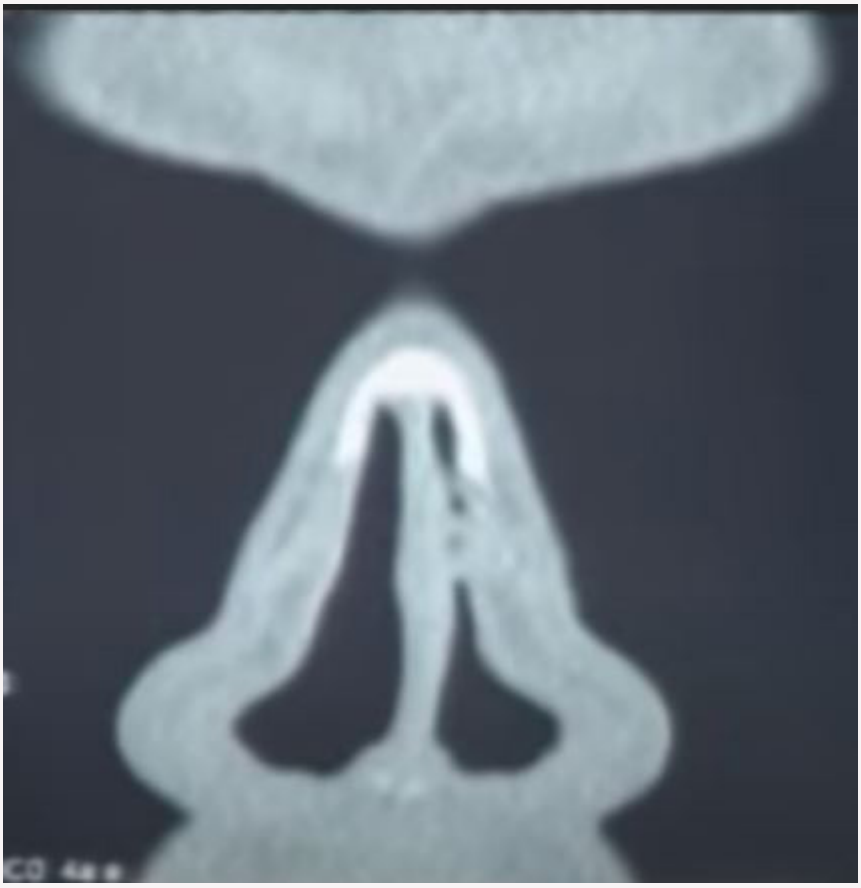


Image showing coronal CT of nose and sinuses Second cut. Note the absence of hollow between the forehead and nose. Arch formed by the nasal bone is clearly visible. The entire cartilaginous portion of nasal septum is clearly seen.

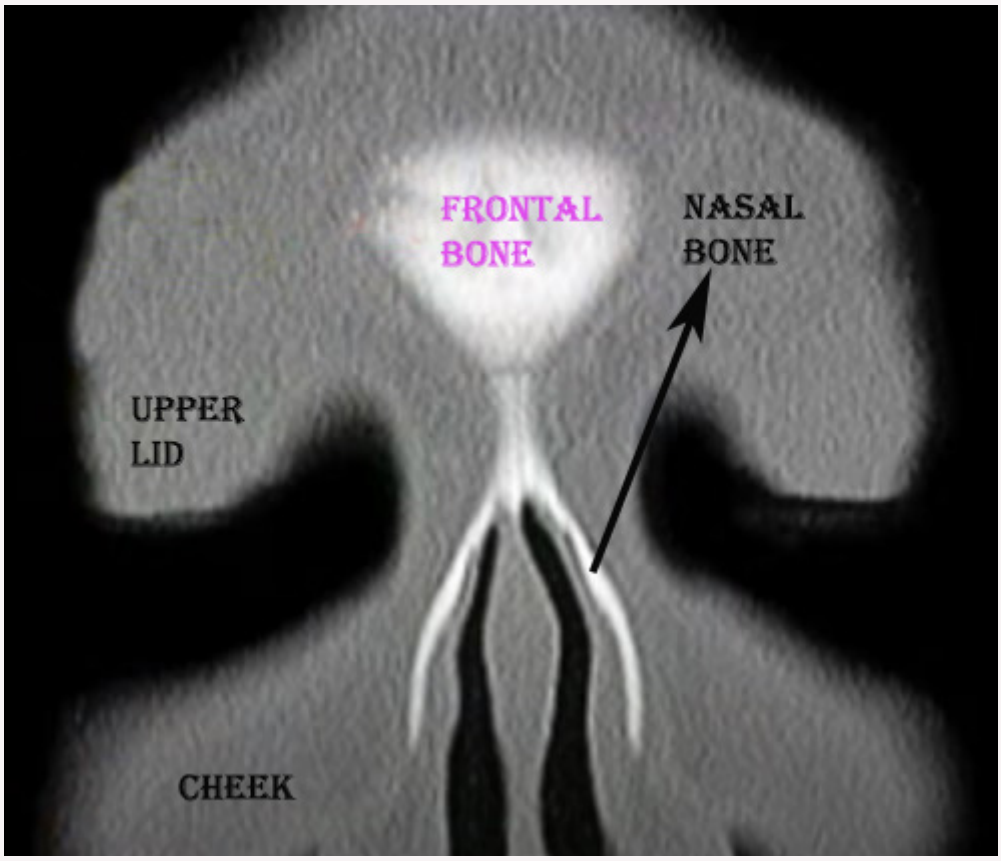


Image showing coronal CT nose and sinuses third cut. Frontal bone is clearly seen. Nasal bones come into view. Upper eye lids are visible. Soft tissue over cheek area is clearly seen. Maxilla is not visible in this view.

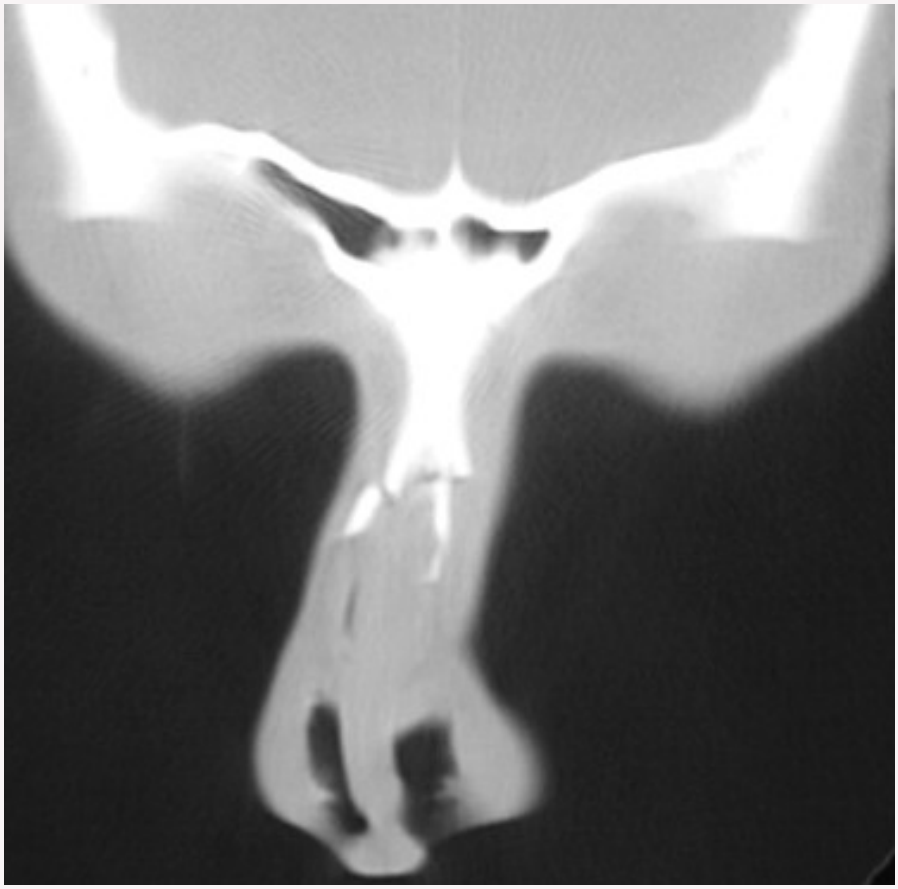


Image of coronal CT nose and sinuses showing fracture nasal bones. Note the inverted 'u' shaped curvature is disturbed. Note the deviation of the lateral nasal cartilages. Frontal sinus is just becoming visible in this cut.

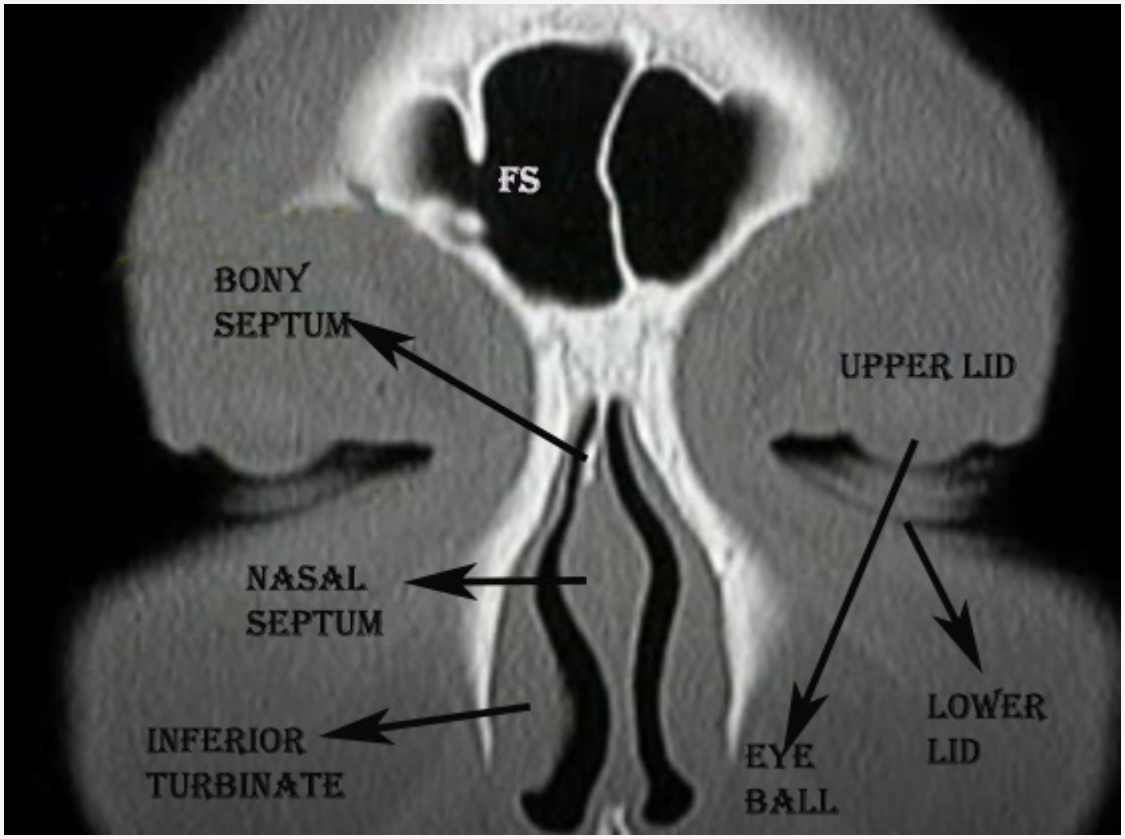


Image showing coronal view of nose and sinuses. In this cut frontal sinus comes into view. Note one complete intersinus septum inside frontal sinus and one incomplete septum. Inferior turbinate comes into view. Upper and lower eyelids are visible. Bony nasal septum is also seen. Septal body is seen as a bulge in the nasal septum. Eye ball is visible in this view.

In the above view frontal bone appears to be pneumatized (frontal sinus seen). Perpendicular plate of ethmoid is seen in the upper part of nasal septum. Note the perpendicular plate of ethmoid which is deviated to the right side. (High septal deviation). Anterior nasal spine is also visible.

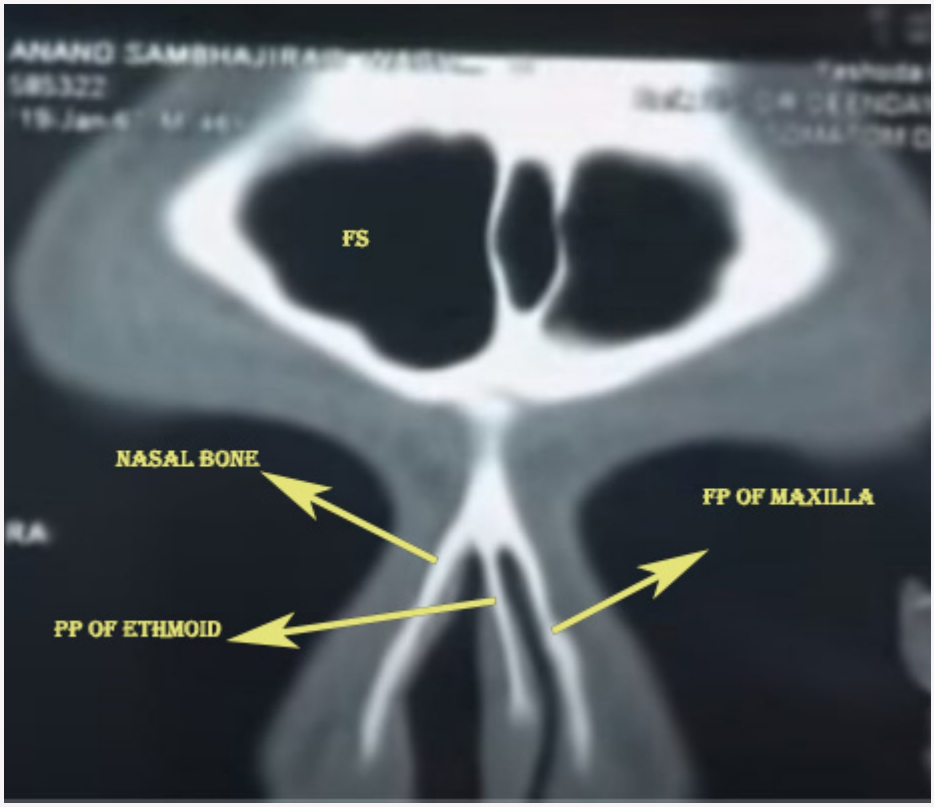


Image showing coronal CT nose and sinuses showing well developed frontal sinus with two intersinus septa. Nasal bone is also seen clearly. Frontal process of maxilla can also be seen. Perpendicular plate of ethmoid deviated to the left is also seen.

It should be stressed that before coming to a conclusion of presence of multiple intersinus septa within the frontal sinus it should be ensured that the same septa should also be present in the posterior cuts also. Frontal process of maxilla can be differentiated from the nasal septum by its extra thickness. Normal sinus cavity will appear black in CT images because air always is seen as black in CT images. In the above image the floor of the frontal sinus is clearly seen as thickened bony area. If the floor of frontal sinus is intact then it means the sinus seen in that area is nothing but frontal sinus. In the posterior cuts the floor of the frontal sinus begin to disappear and frontal recess area (frontal sinus drainage path) becomes clearly visible.

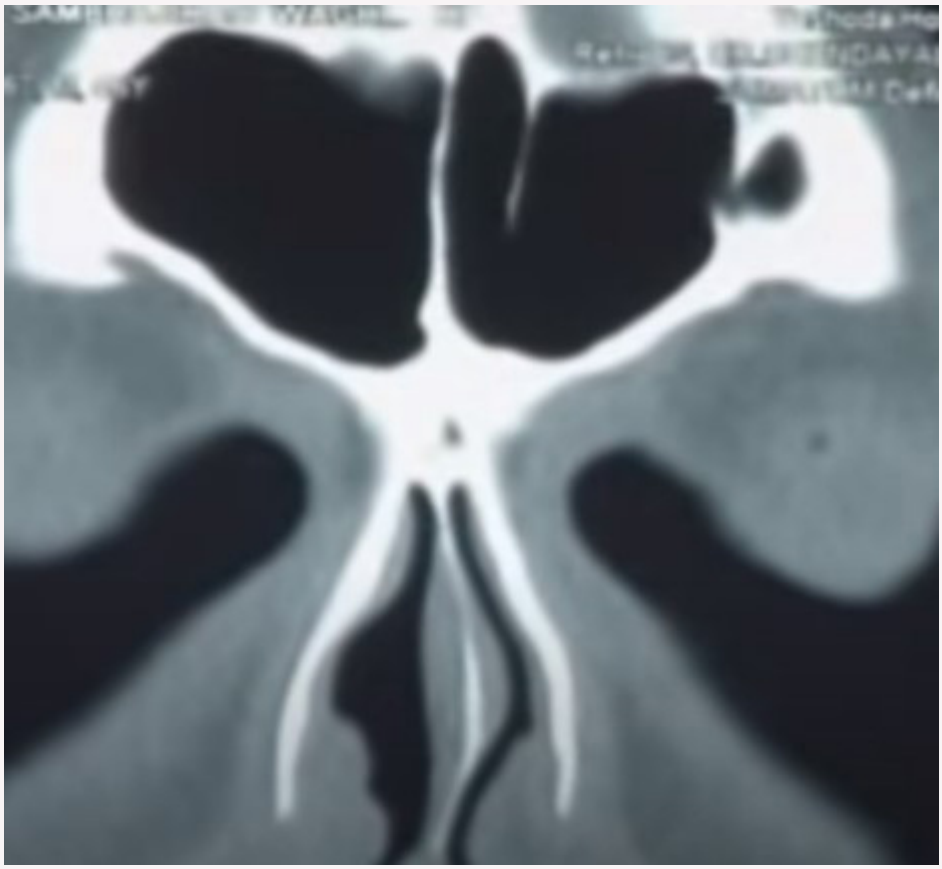


Image showing CT coronal section of nose and sinuses showing well pneumatized frontal sinus. Floor of the frontal sinus is clearly seen and thick. Intersinus septa which was two in number in the previous cut, now shows one complete septa and another incomplete one. In order to come to a conclusion of multiple intersinus septa in the frontal sinus the same septa should also be visible in the posterior cuts of scan. Inferior turbinate makes its appearance in this cut. Begining of the orbit is also seen.

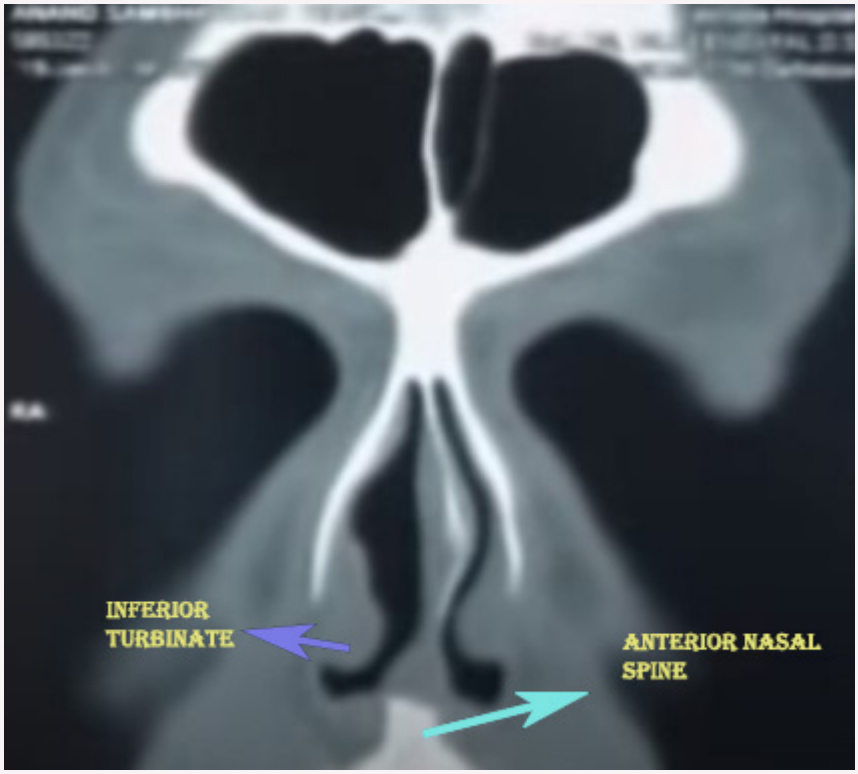


Image showing Coronal CT nose and sinuses taken at the level of anterior nasal spine. The image reveals the anterior nasal spine, inferior turbinate and deviated nasal septum. Perpendicular plate of ethmoid is also clearly visible. Two intersinus septa are seen within the frontal sinus.

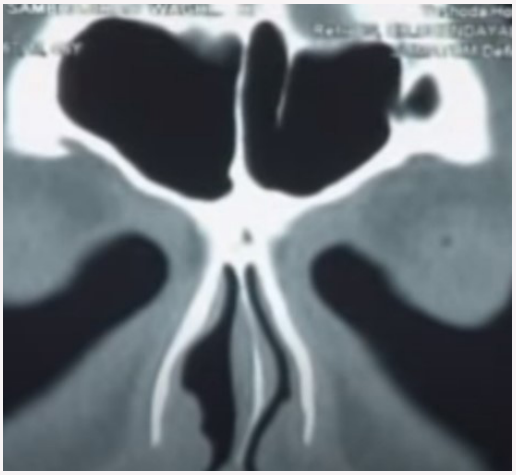


Image showing the next coronal cut showing one complete and one incomplete septa within the frontal sinus. Floor of the frontal sinus is complete and is thickened. This feature indicates that sinuses revealed are the frontal sinus. Inferior turbinate is visible. Nasal septum is found deviated to the left side

Image showing coronal section of nose and sinuses. In this cut orbit starts to become visible. Floor of the frontal sinus is complete and thickened. So the pneumatized area in the frontal bone should be the frontal sinus. One complete intersinus septa and one incomplete septa within the frontal sinus is visible.

Image showing coronal CT of nose and sinuses. In this cut maxillary sinus starts to appear. Floor of the frontal sinus begins to change, but is still present. Frontal sinus is still present in this cut. Inferior turbinate is clearly seen. Interfrontal sinus septum (single is seen). Multiple septa within the frontal sinus shown in earlier cuts are not visible in this cut. Frontal sinus septa should be present in all cuts for it to be termed as interfrontal sinus septa. Orbit is also clearly seen. Deviated nasal septum to the right is also seen. Enlargement seen in the nasal septum indicates the presence of nasal septal turbinate (also known as the septal body) which is nothing but an erectile tissue found in the nasal septum.

Nasal septal turbinate (Septal body):

This is a thickening located in the anterosuperior segment of the nasal septum. It was Morgagni in 1706, who described this structure as a thickening of mucosa in the anterior part of nasal septum. This thickening is visible both during anterior rhinoscopy, endoscopic examination of nasal cavity and in imaging. This area is located on the border of the cartilage of the quadrangular portion of the nasal septum at the junction with the perpendicular plate of ethmoid bone and is present bilaterally. This structure is located anterior to the osteomeatal complex.

Schiefferdecker in 1900 performed histological studies from this area and determined that his thickening had a vascular structure, very similar to that of turbinates and hence coined the term septal turbinate.

Other names used to indicate this area include:

1. Nasal septal swell body

2. Septal intumescence

3. Anterior septal tuberculum

4. Septal erectile body

5. Tuberculum of Zuckerkandl

6. Kisselbach's ridge

The air current that flows through the nasal cavity during inspiration, in the presence of septal body changes direction towards the anterior end of the middle turbinate. This structure divides the air current into two parts. One portion of the inspired air flows into the common nasal meatus and superior nasal meatus, while the other is directed under the middle turbinate into the osteomeatal complex. Air current divided in this manner ensures that there is greater contact between it and the nasal mucosa ensuring adequate warming and humidification of inspired air.

Nasal septal turbinate is seen in 50% of normal population. It is found to have a thicker mucosa and more abundant mucous glands and vascular plexus compared to the mucosa of other nasal areas.

Presence of septal turbinate affects the width of the internal nasal valve. It is often thought to have little clinical significance and is rarely considered when planning for surgical management.

Decreasing volume of this mass by coblating it has been known to increase the patency of the nasal cavity.

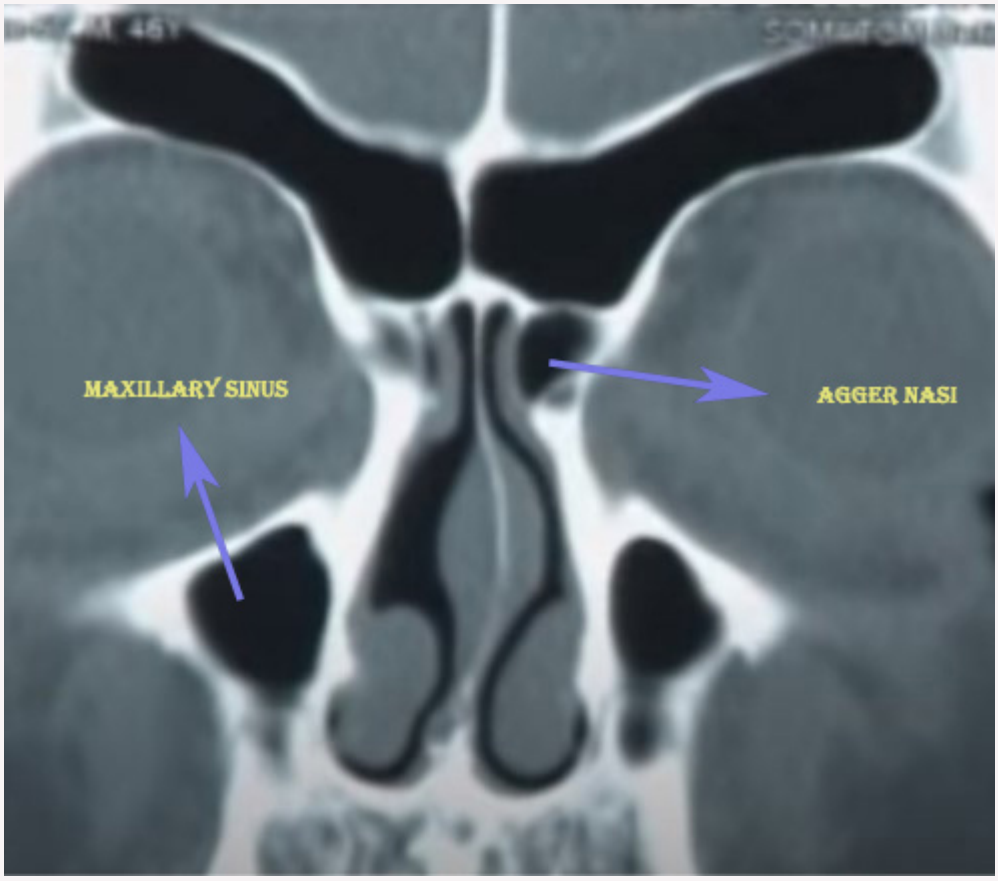


Image showing Coronal CT of nose and sinuses. In this cut maxillary sinus is seen. Floor of frontal sinus is also seen. Agger nasi cells are seen. This is formed by pneumatization of the lacrimal bone. Frontonasal process is also clearly seen.

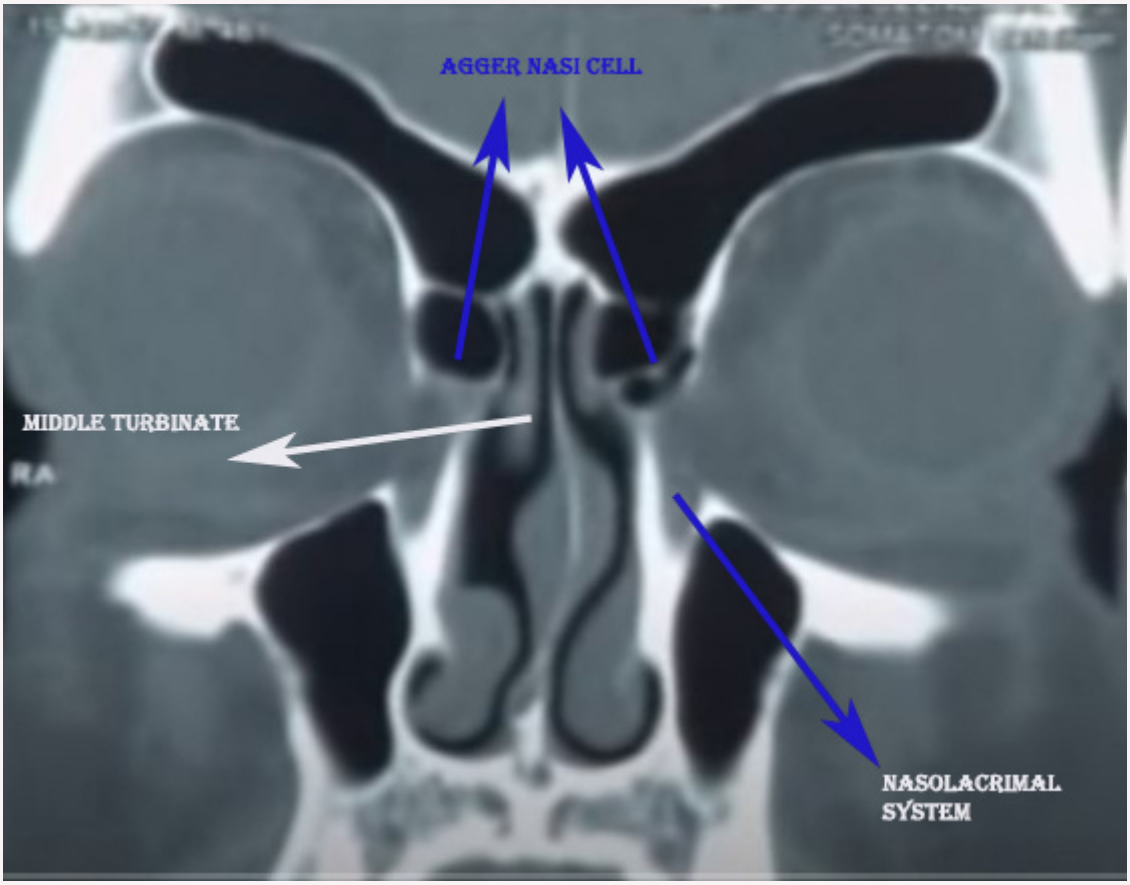


Image showing coronal CT nose and sinuses. In this cut note the floor of the frontal sinus is gone indicating that the level where frontal sinus drains (posterior portion of frontal sinus) has been reached in this cut. Prominent agger nasi cell seen. Middle turbinate is seen appearing for the first time in this cut. Nasolacrimal system is also seen in this cut. Anatomically agger nasi cell (anterior most ethmoidal air cell) lies in front and just below the frontal sinus drainage tract. Infection of this air cell can cause obstruction to the drainage of frontal sinus. Frontal sinus drainage tract can be accessed by opening up the agger nasi air cell during endoscopic sinus surgery.

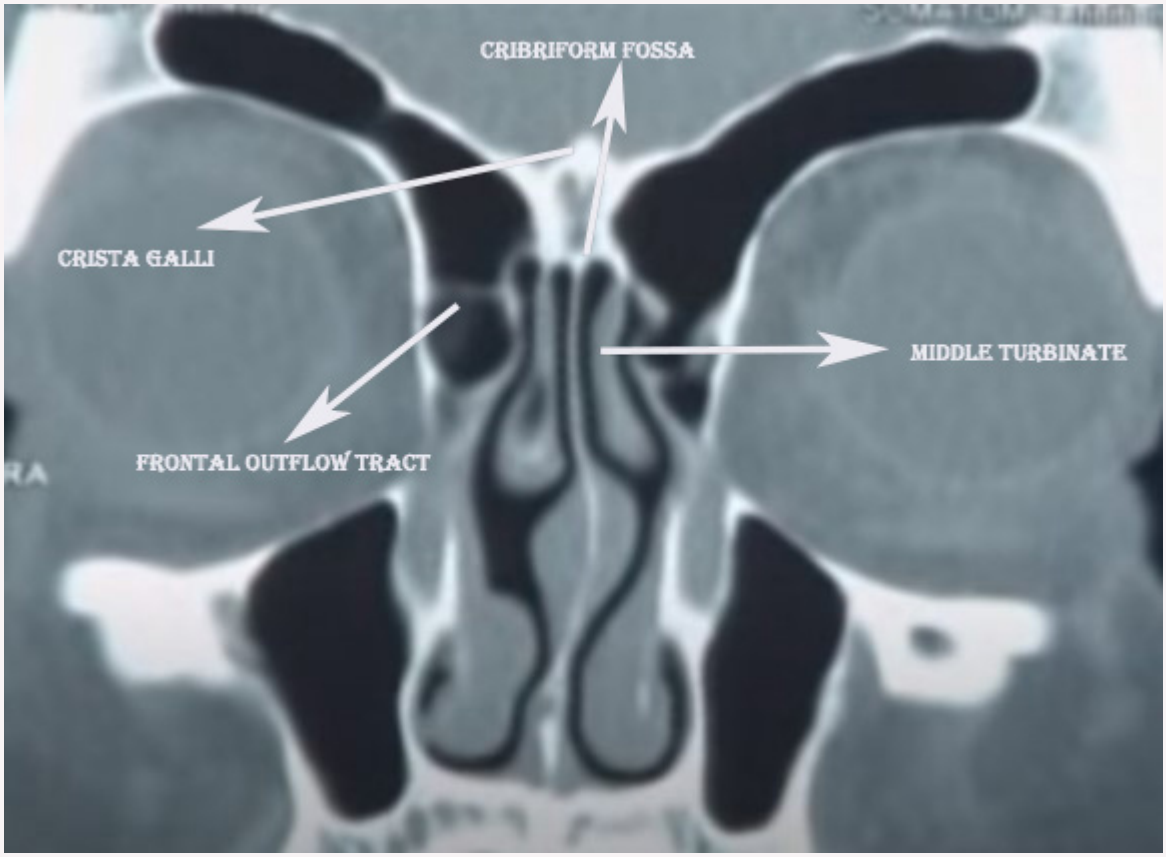


Image showing coronal CT nose and sinuses. The floor of the frontal sinus is totally absent indicating that this cut is posterior to the frontal sinus demonstrating the frontal outflow tract. Crista galli is also seen in this cut. Middle turbinate is found attached to the lateral lamella of the cribriform fossa. Shape and size of frontal recess is decided by the surrounding structures and the most important being the agger nasi. Hence once the agger nasi is removed then the frontal recess will be uncovered. Air filled space in the frontal area is not the frontal sinus since the floor of the sinus is not visible. It is the supraorbital recess area.

Frontal recess:

It is also known as the nasofrontal duct. It does not have bony walls of its own and hence it is more appropriately referred to as the recess rather than the duct.

Anatomy of the frontal recess is highly variable and complex depending on the presence of frontal recess cells and bulla lamella (bulla ethmoidalis). It appears like an inverted funnel with the apex at the frontal ostium. Together with the frontal infundibulum and frontal ostium, it forms the frontal sinus outflow tract.

Borders:

1. Anterior - Frontal recess cells (commonly the agger nasi cell)

2. Medial - Middle turbinate

3. Lateral - Medial wall of the orbit

Posterior margin is variable depending on whether the bulla is complete and whether it reaches the skull base. It present the suprabullar cell may also contribute to the posterior boundary.

Frontal recess drains into the middle meatus, or ethmoid infundibulum. Direct drainage into the suprabullar and retrobullar recess is possible when the bulla is incomplete.

Patency of frontal recess depends on the following structures:

1. Superior articulation of the uncinate process

2. Agger nasi cells

3. Presence or absence of frontal recess cells

4. Supraorbital cell

5. Bulla ethmoidalis

Agger nasi cells:

The term agger nasi means nasal mound in Latin.

These cells are the anterior most ethmoidal cells lying anterolateral and inferior to the frontal recess and anterior and above the attachment of the middle turbinate. This cell is located within the lacrimal bone hence it is laterally related to the orbit, lacrimal sac and the nasolacrimal duct. These cells should not be confused with Haller cells which are located along the medial floor of the orbit or the supraorbital cells which is located in the roof of the orbit.

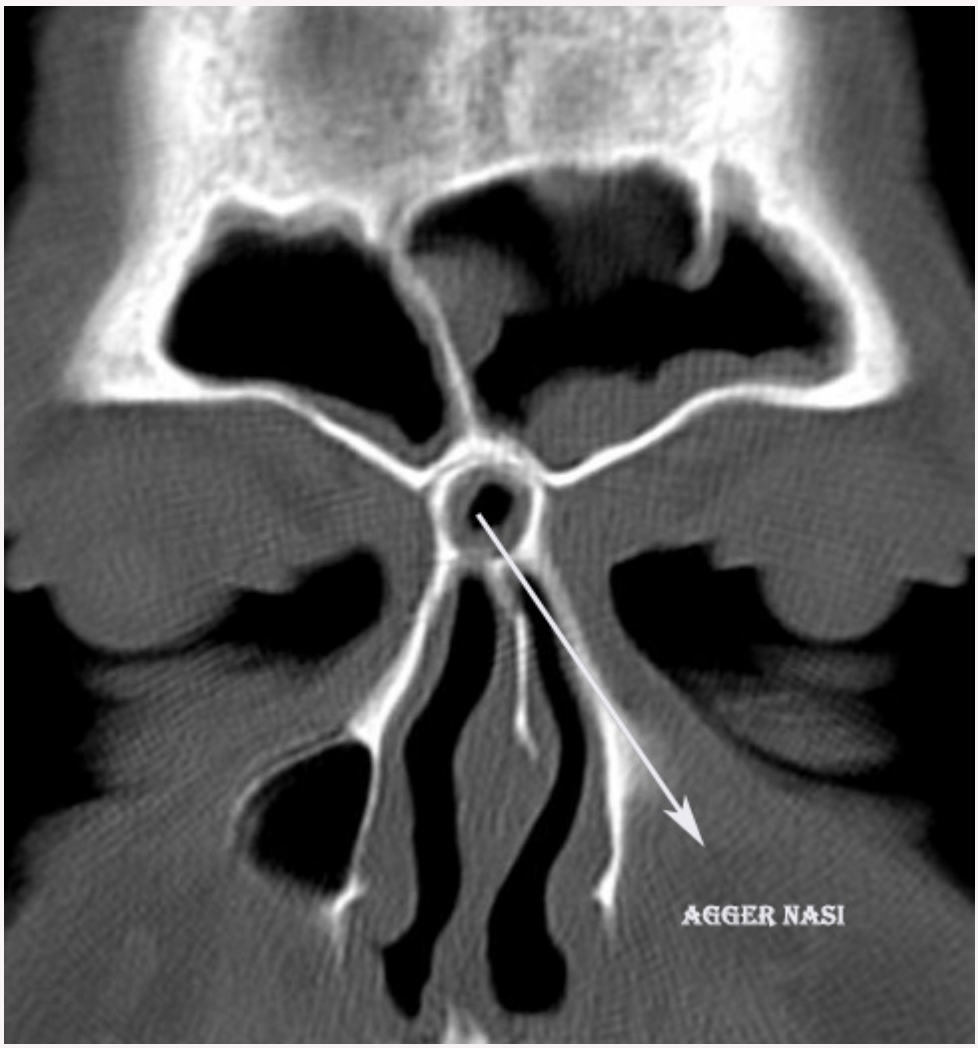


Image showing coronal CT nose and sinuses agger nasi cell with mucosal thickening within it. It is slightly anterior cut when compared with that of the next image. Note the floor of the frontal sinus is intact.

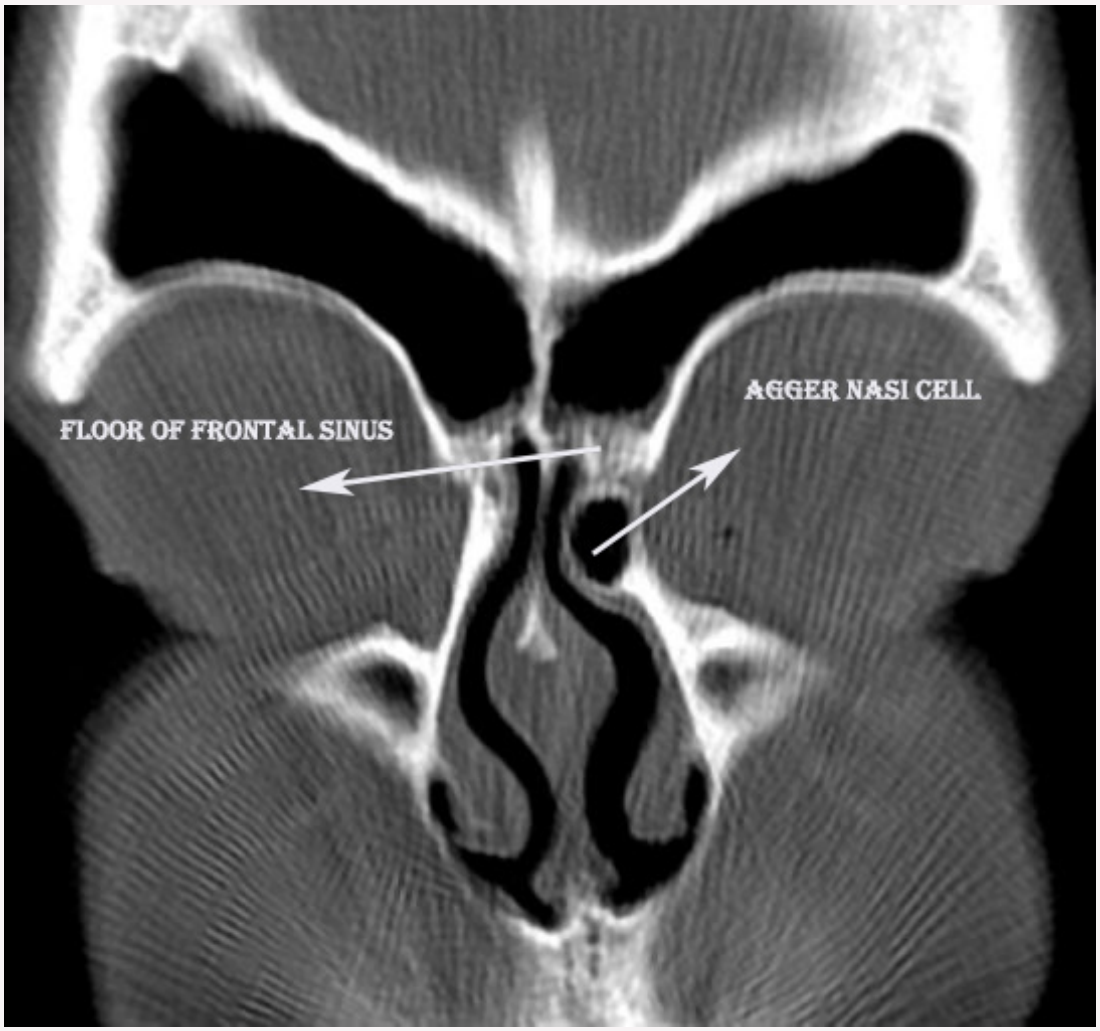


Image showing agger nasi cell. Note the floor of the frontal sinus is intact indicating that this coronal CT PNS cut is demonstrating the frontal sinus and its outflow tract will be demonstrated only in the posterior cuts as the frontal sinus drainage channel lies posterior to it. In order to ascertain whether the structure demonstrated is frontal sinus the presence of a bony bridge between lamina papyracea and the perpendicular plate of ethmoid should be looked for. If this bony bridge is present then it is the frontal sinus. It is also known as the T sign / M sign. Absence of this bony bridge between the lamina papyracea and the perpendicular plate of ethmoid indicates that the structure displayed is the frontal recess area.

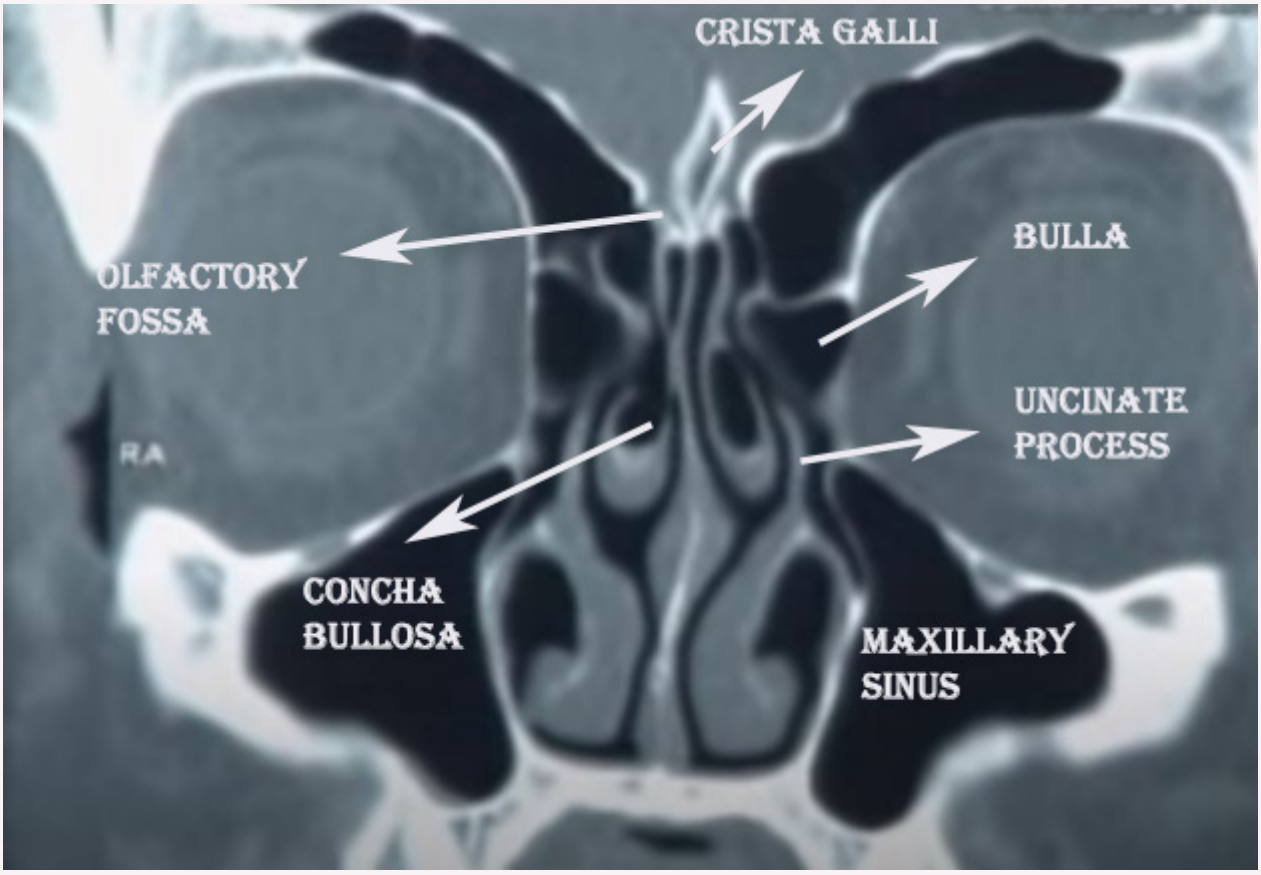


Image showing Coronal CT of nose and sinuses. In this cut Bulla ethmoidalis (middle ethmoid air cell) is visible. Middle turbinate is pneumatized bilaterally (concha bullosa). Middle turbinate could be seen attached superiorly to the lateral lamella of the olfactory fossa. Uncinate process is visible. Its lower attachment is to the inferior turbinate always. Only its superior attachment is variable.

Concha bullosa:

Sometimes middle turbinate may become pneumatized. This pneumatization is known as concha bullosa. This process of pneumatization starts either from frontal recess or agger nasi air cells. This is usually considered to be a normal variant. Sometimes this pneumatization may become so extensive that it could cause obstruction in Osteomeatal complex.

Bolger classified pneumatization of middle turbinate into three types:

Lamellar type pneumatization: This involves pneumatization of vertical lamella of middle turbinate.

Bulbous type pneumatization: Involves pneumatization of inferior portion of middle turbinate.

Extensive pneumatization: Involves pneumatization of both lamellar portion and inferior portion of

middle turbinate. It is also known as Concha bullosa.

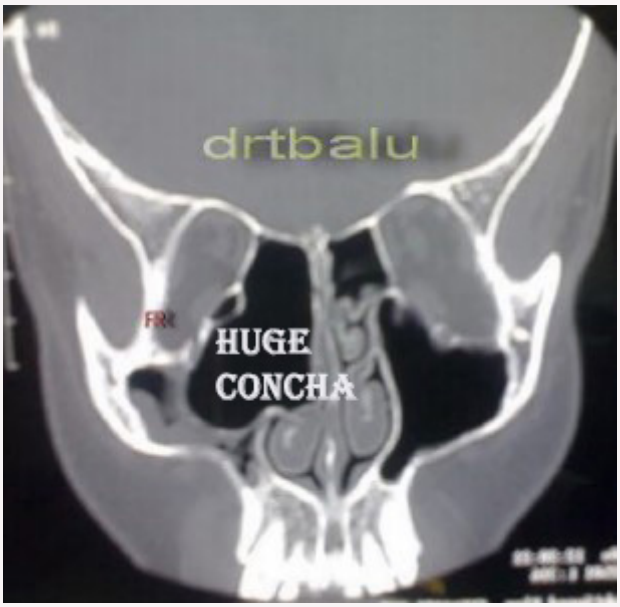


Image showing a huge concha bullosa on the right side encroaching into the right maxillary sinus. Presence of a large concha bullosa could hamper drainage of the middle meatus.

Between the uncinate process and bulla lie the hiatus semilunaris inferioris which is a two dimensional space and it opens into a three dimensional space known as the infundibulum. This is best seen in axial and sagittal sections of CT images.

Paradoxical middle turbinate:

This is an anatomical variation that could cause nasal obstruction. The middle turbinate is curved inferomedially in such a way that the concave surface of the turbinate faces the nasal septum. It usually occurs bilaterally. When associated with concha bullosa it could cause significant nasal obstruction.

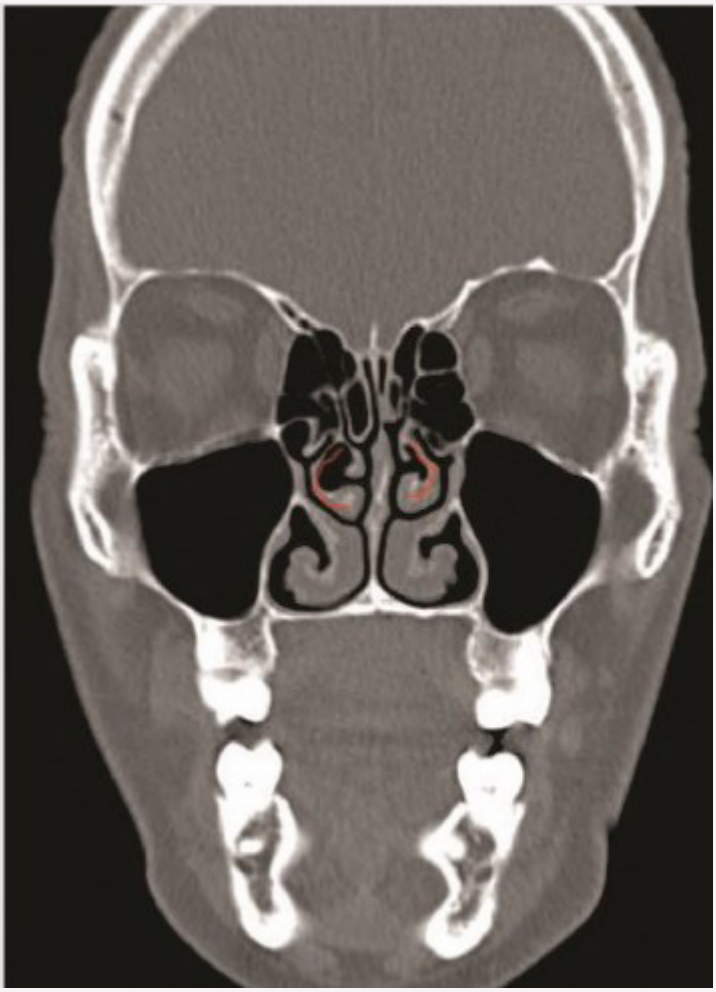


Image showing coronal CT of nose and sinuses showing paradoxically bent middle turbinate

Haller cell:

These air cells belong to the anterior ethmoidal air cell group. They are also known as infraorbital ethmoid air cells or maxillo ethmoid air cells. These cells invariably extend into the inferomedial portion of the orbital floor. These cells are commonly seen in 40% of patients. This air cell is named after Albrect von Haller the Swedish anatomist who first described these cells. In majority of patients Haller cells may be asymptomatic.

Radiological classification of Haller cell:

1. Small

2. Medium

3. Large

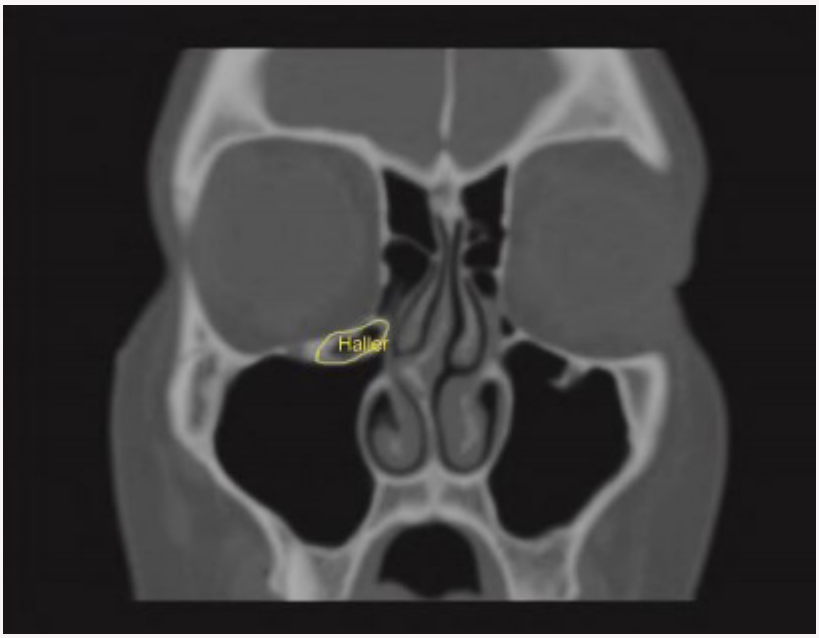


Image showing infraorbital air cell (Haller cell) marked in yellow on the right side. Also note the presence of septal spur to the right. Infraorbital nerve is seen on the left side along the infraorbital border within the left maxillary sinus.

Image showing Axial CT scan of nose and sinuses showing Haller cell. This image is included to make the reader aware of the differences in orientation between coronal and axial sections of CT scan images.

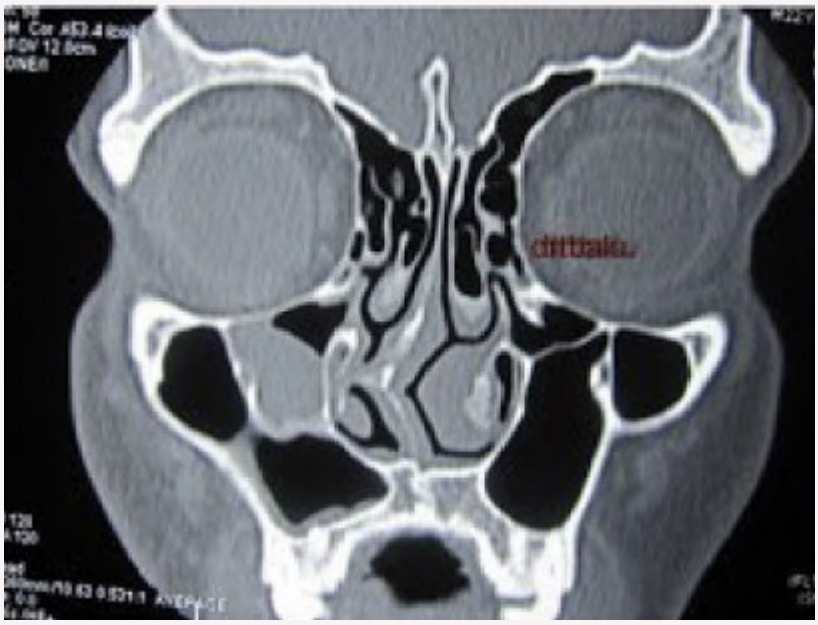


Image showing a large infected Haller air cell on the right side in the coronal CT image of nose and sinuses

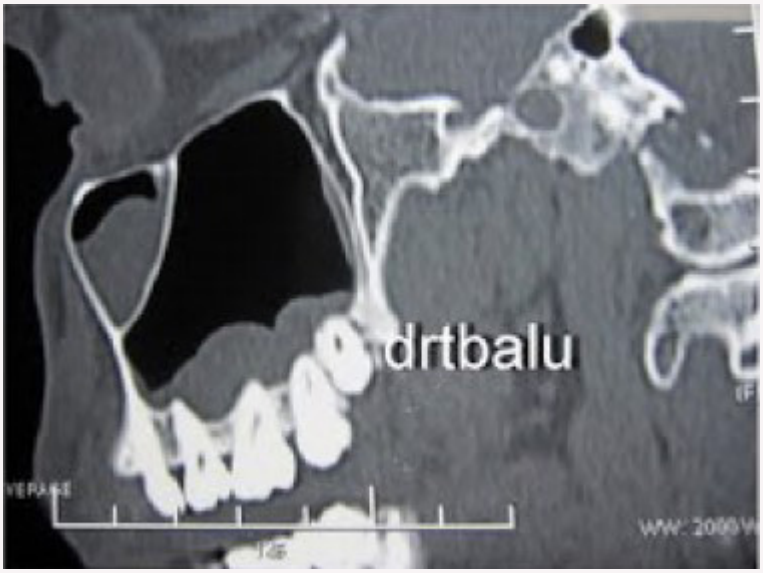


Image showing large infected Haller cell as seen in the lateral view of CT nose and sinuses. Haller cell is clearly seen below the orbit

In the presence of large Haller cell along with Bulla ethmoidalis and concha bullosa, the concha drains via the suprabullar recess.

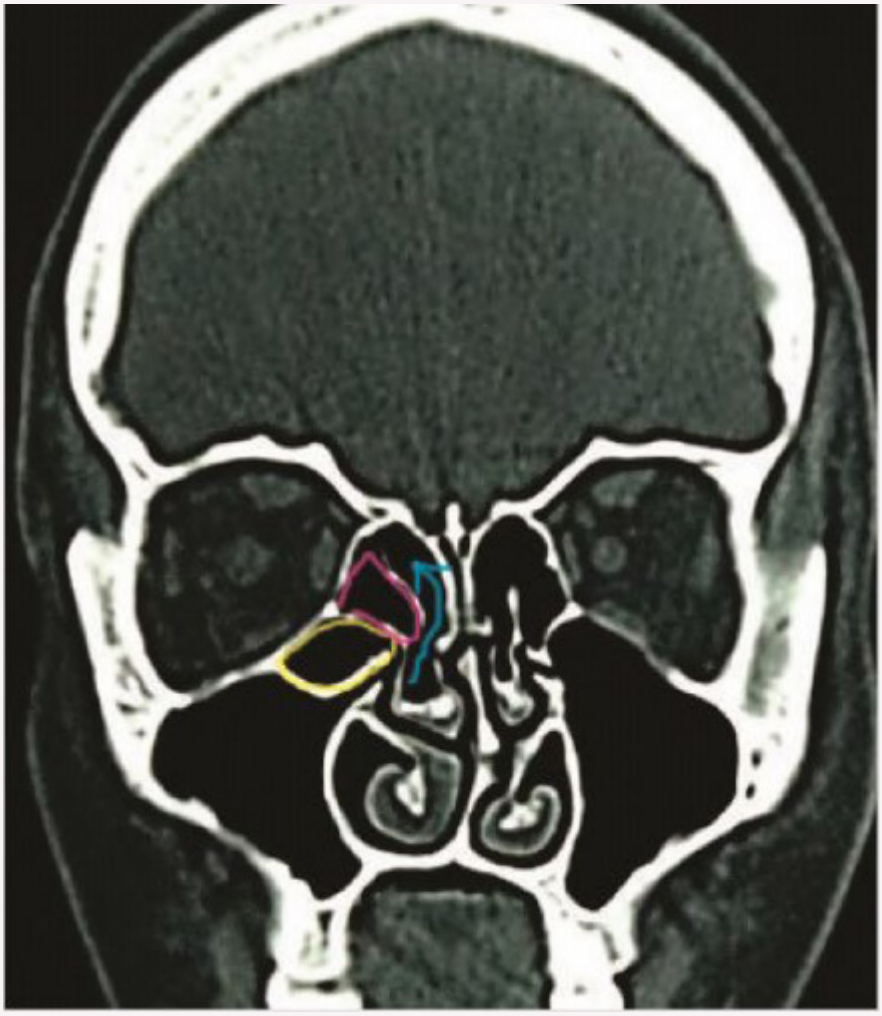


Image showing coronal CT of nose and sinuses demonstrating suprabullar recess. Haller cell is marked in yellow, Bulla is marked in pink and the drainage of concha bullosa into the suprabullar recess is marked by a blue arrow.

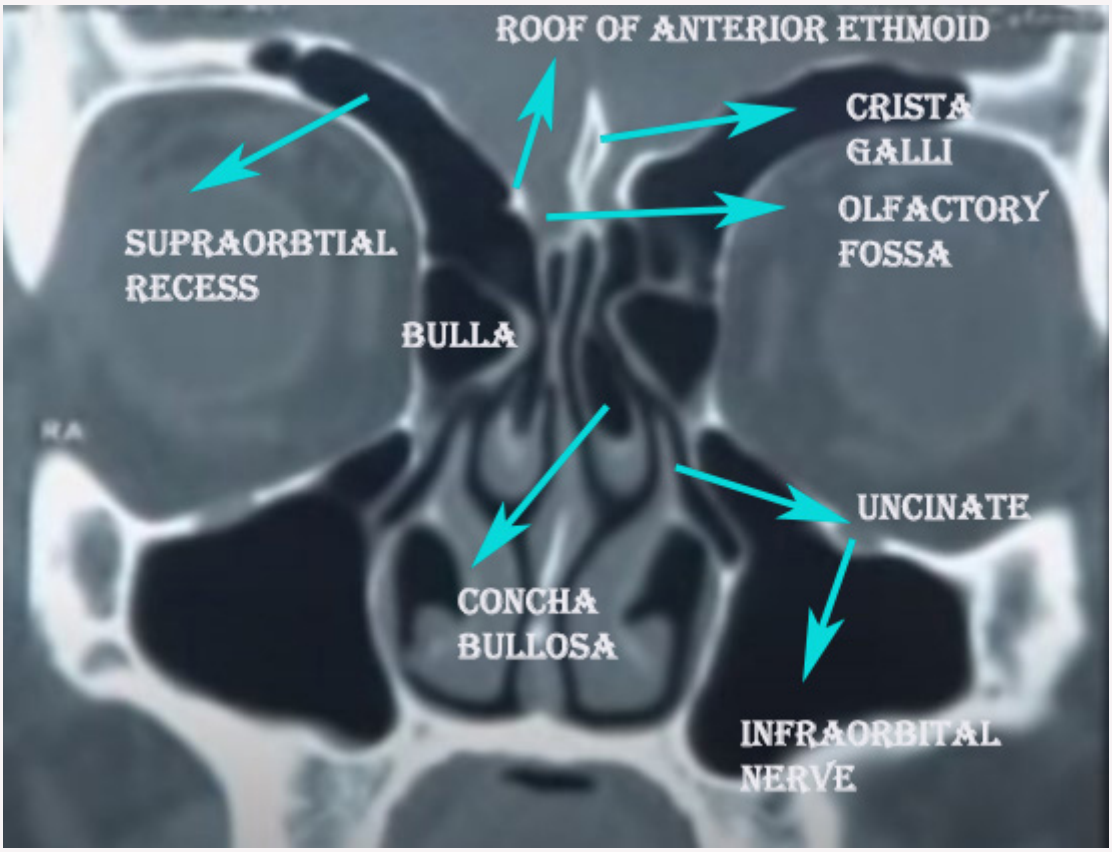


Image showing coronal CT of nose and sinuses showing supraorbital recess. Note the loss of floor of frontal sinus indicating that this cut has been taken behind the frontal sinus. Frontal sinus outflow tract is also clearly seen. Other structures seen in this cut normally are named. Note the concha bullosa draining into the suprabullar recess.

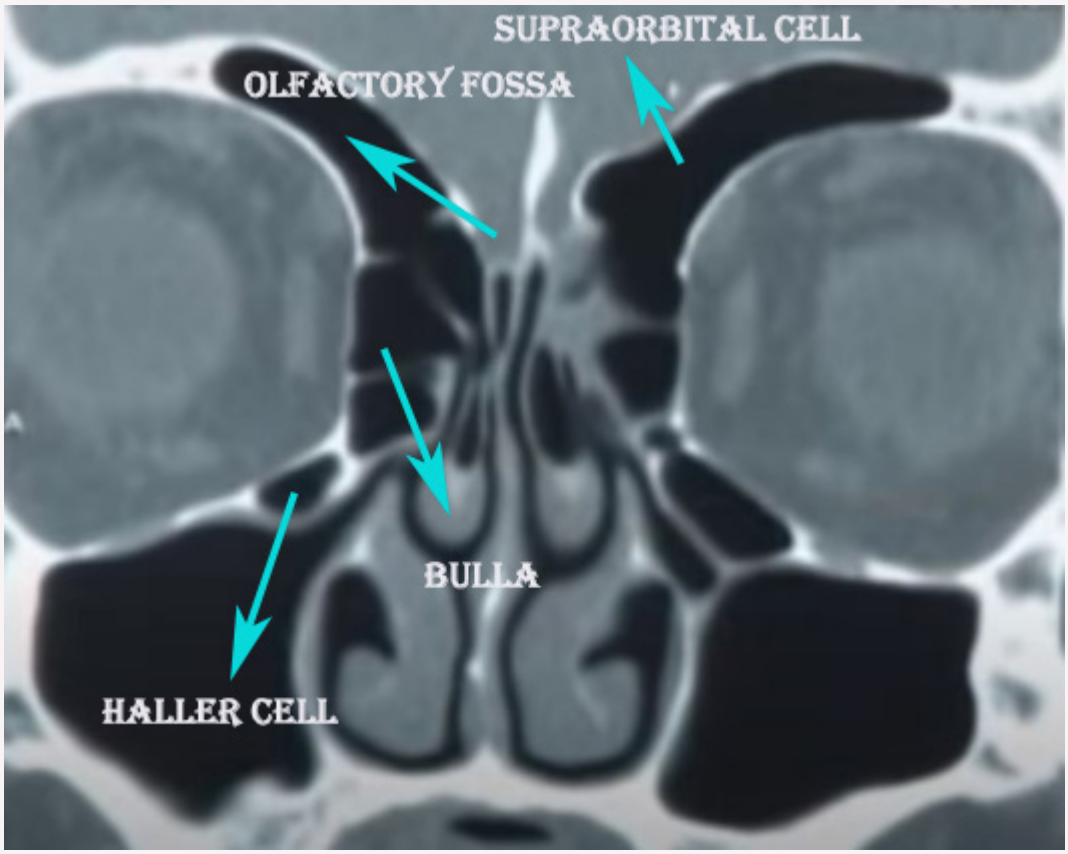


Image showing the next coronal cut. In this cut more anterior ethmoidal air cells come into view. Haller cell, and bulla ethmoidalis is also seen. Middle turbinate is attached superiorly to the lateral lamella of the olfactory fossa. This area happens to be the weakest point of olfactory fossa. Rough manipulation of middle turbinate during FESS surgery could cause damage to this area leading onto CSF leak.

Ethmoid sinus:

This is situated lateral to the olfactory fossa, between lateral nasal wall and medial wall of orbit. This sinus is the most compartmentalized of all paranasal sinuses, hence it shows the maximum anatomical variations. At birth only a few ethmoid air cells are pneumatized, this number swells to 20 as adult hood is reached. For easy and better understanding ethmoidal labyrinth is divided by 5 obliquely directed parallel lamella.

1. First lamella (anterior lamella): This is the uncinate process, which embryologically corresponds to the basal lamella of first ethmoturbinal.

2. Second lamella: This is the ethmoid bulla (Bulla ethmoidalis). This is the most constant of all ethmoid air cells. According to Zuckerkandl 10this is the largest of all anterior ethmoid air cells.

3. Third lamella: This is the most important. It is the basal lamella of middle turbinate separating anterior from posterior ethmoid air cells. This is the exact surgical posterior limit of anterior ethmoidectomy.

4. Fourth lamella: Is the basal lamella of superior turbinate.

5. Fifth lamella: is the basal lamella of supreme turbinate.

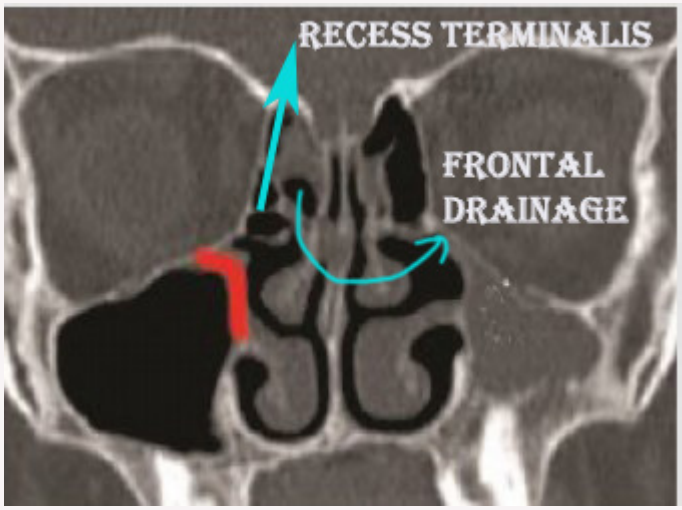


Image showing type I insertion of uncinate process (marked in red)

Here the uncinate process bends laterally in its upper most portion and inserts into the lamina papyracea. Here the ethmoidal infundibulum is closed superiorly by a blind pouch called the recessus terminalis (terminal recess).

In this case the ethmoidal infundibulum and the frontal recess are separated from each other so that the frontal recess opens in to the middle meatus medial to the ethmoidal infundibulum, between the uncinate process and the middle turbinate. The route of drainage and ventilation of the frontal sinus run medial to the ethmoidal infundibulum.

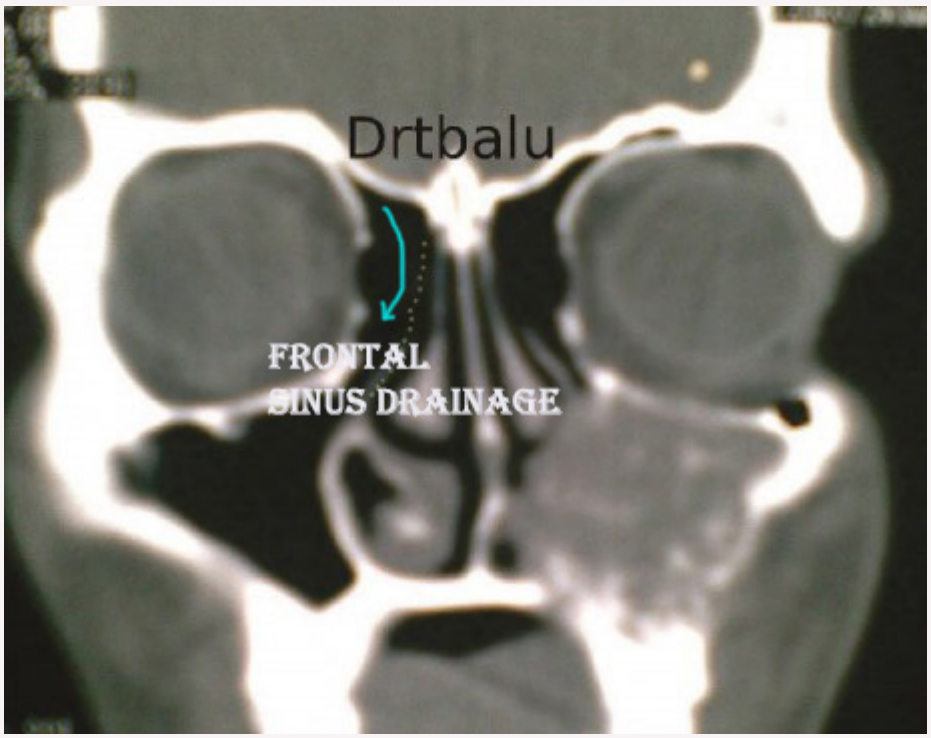


Image showing Type II uncinate insertion

Here the uncinate process extends superiorly to the roof of the ethmoid. The frontal sinus opens directly into the ethmoidal infundibulum. In these cases a disease in the frontal recess may spread to involve the ethmoidal infundibulum and the maxillary sinus secondarily. Sometimes the superior end of the uncinate process may get divided into three branches one getting attached to the roof of the ethmoid, one getting attached to the lamina papyracea, and the last getting attached to the middle turbinate.

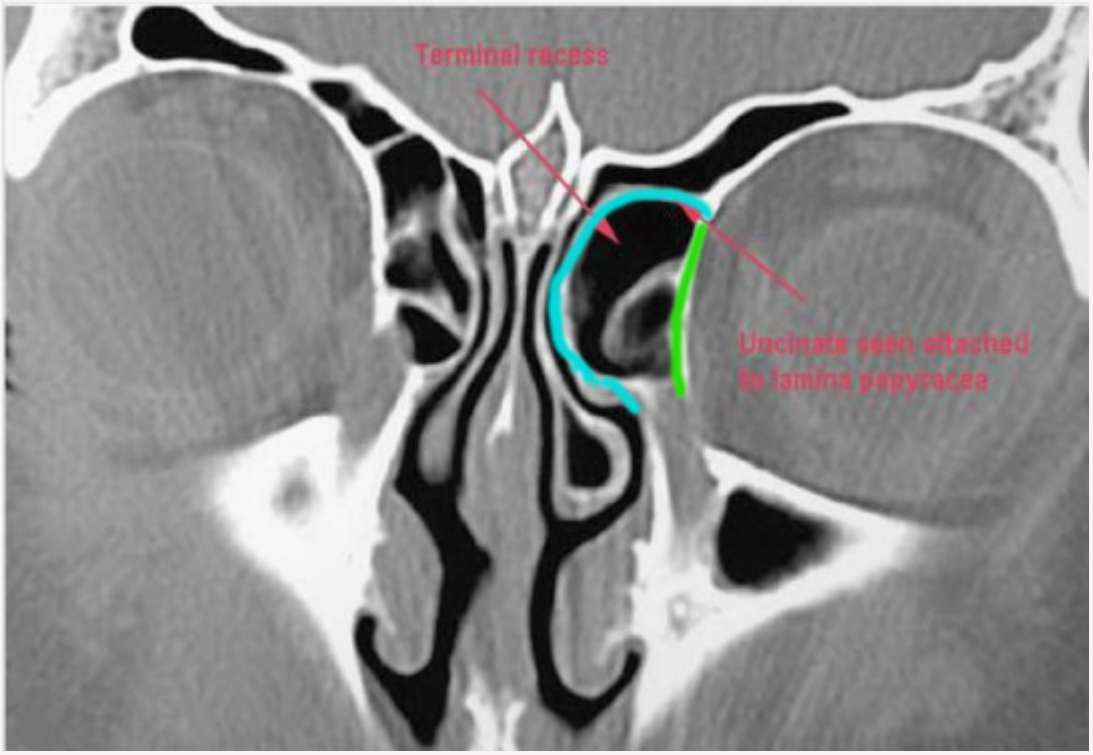


Image showing coronal CT of nose and sinuses with Type I attachment of uncinate. Note uncinate (blue) getting attached to lamina papyracea (green). Terminal recess is clearly seen in this cut. Frontal sinus could be seen draining medial to the infundibulum

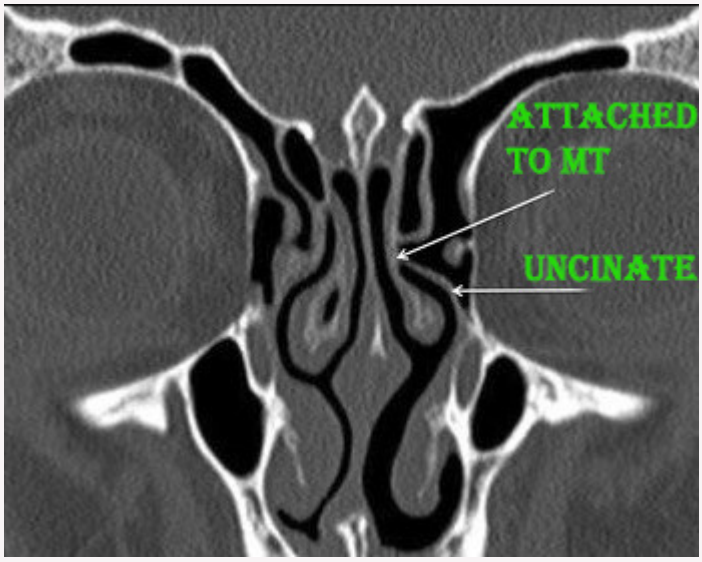


Image showing Coronal CT nose and sinuses showing uncinate process attached to the middle turbinate (type III insertion of uncinate).

Type III uncinate process:

In this type the superior end of the uncinate process turns medially to get attached to the middle turbinate. Here also the frontal sinus drains directly into the ethmoidal infundibulum.
Uncinate process should be removed in all endoscopic sinus surgical procedures in order to open up the middle meatus. In fact this is the first step in endoscopic sinus surgery.

Rarely the uncinate process itself may be heavily pneumatized causing obstruction to the infundibulum.

Pneumatized Uncinate process:

Uncinate process can be pneumatized causing narrowing of Osteomeatal complex. The exact mechanism of uncinate pneumatization is not known. It could be due to growth of agger nasi cells into the most anterosuperior region of uncinate process.

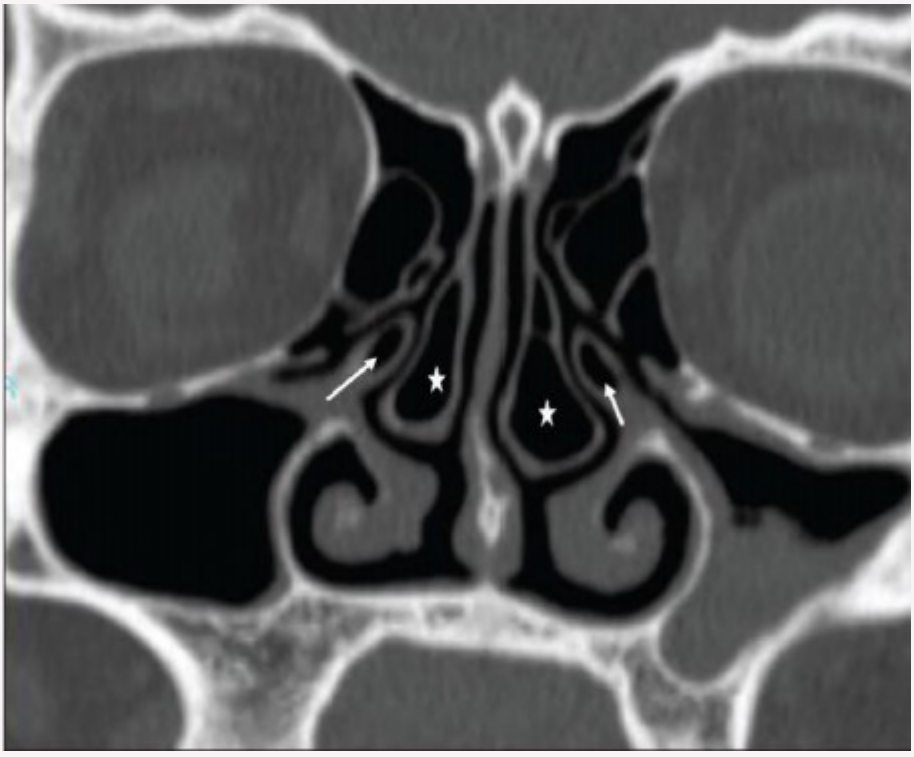


Image showing Coronal CT of nose and sinuses showing pneumatized uncinate process (white arrows) and pneumatized middle turbinate (*)

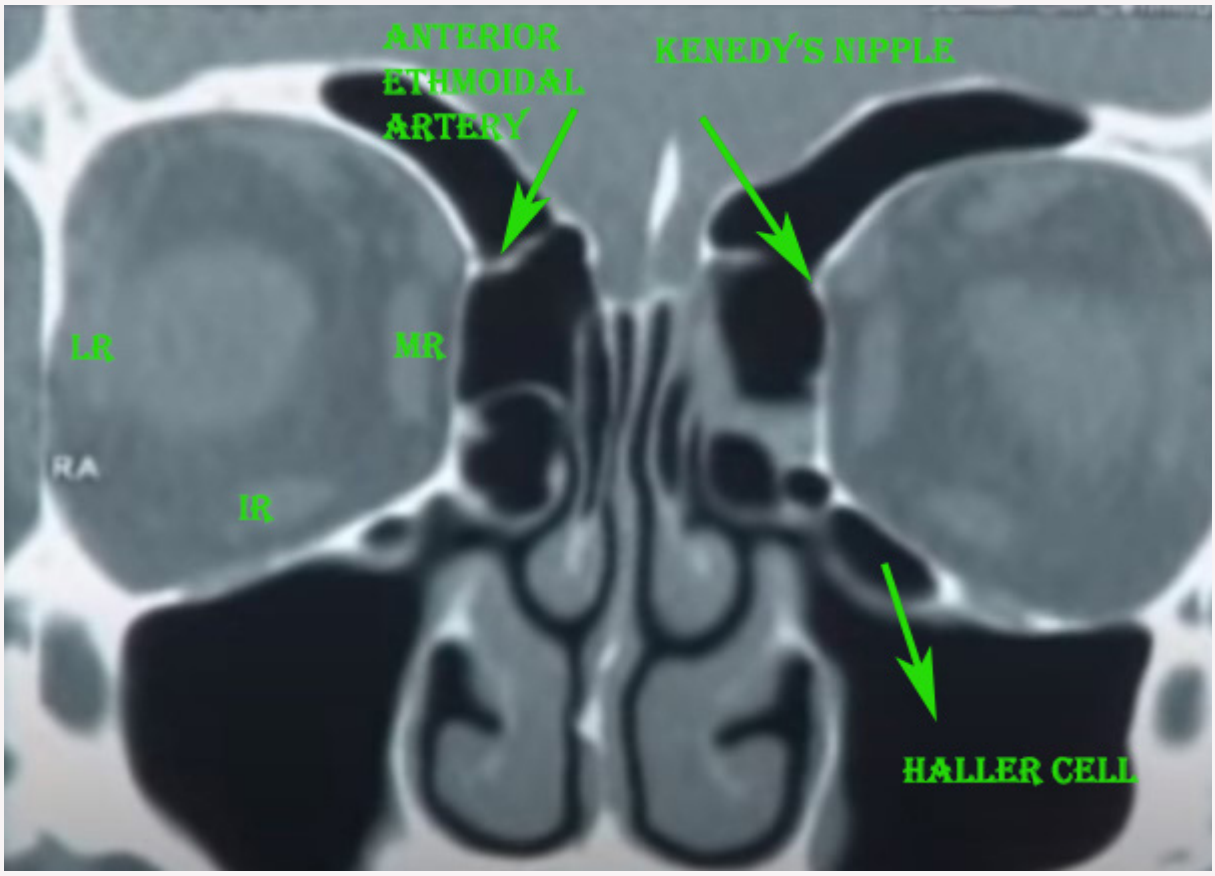


Image showing coronal CT of nose and sinuses. Structures seen include:

Kennedy's Nipple - The point from which the anterior ethmoidal artery exits the orbit. This point is located at the junction of the medial rectus with that of superior oblique. Anterior ethmoidal artery is seen occupying the floor of the frontal sinus outflow tract. Orbit takes a conical shape. Intraocular muscles are visible which include:

1. MR - Medial rectus

2. Inferior rectus

3. Lateral rectus

Lamina papyracea: "Meaning paper thin in Latin".

This forms the medial wall of the orbit. It is a thin plate of bone. It is also known as the orbital lamina of the ethmoid bone. This bone forms the lateral surface of the ethmoid air cells.

Articulations of lamina papyracea:

It articulates:

Superiorly with the orbital plate of frontal bone.

Inferiorly with the maxilla and orbital process of the palatine bone.

Anteriorly with the lacrimal bone.

Posteriorly with the sphenoid bone.

This bone thickens posteriorly to form the optic tubercle protecting the optic nerve.

Dehiscence of lamina papyracea:

These patients have defect of the medial wall of orbit. This condition is considered to be a benign congenital variant and has no clinical significance. The presence of this condition should be documented prior to FESS because prior knowledge of this variation would ensure that the surgeon would be careful while operating in this area. This condition could be caused by hyperareated ethmoid.

Image showing dehiscence of lamina papyracea (green asterix)

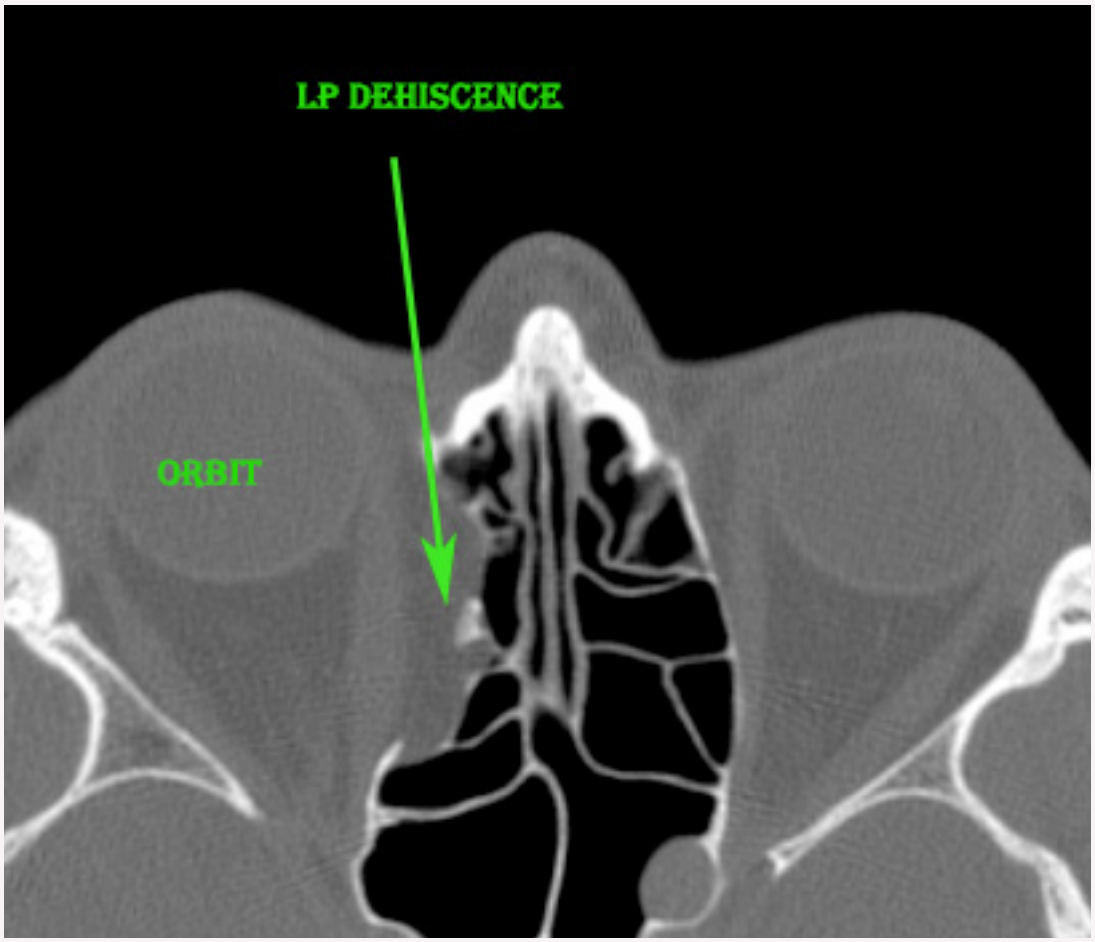


Image showing CT axial view of nose and sinuses showing dehiscence of lamina papyracea (Green arrow)

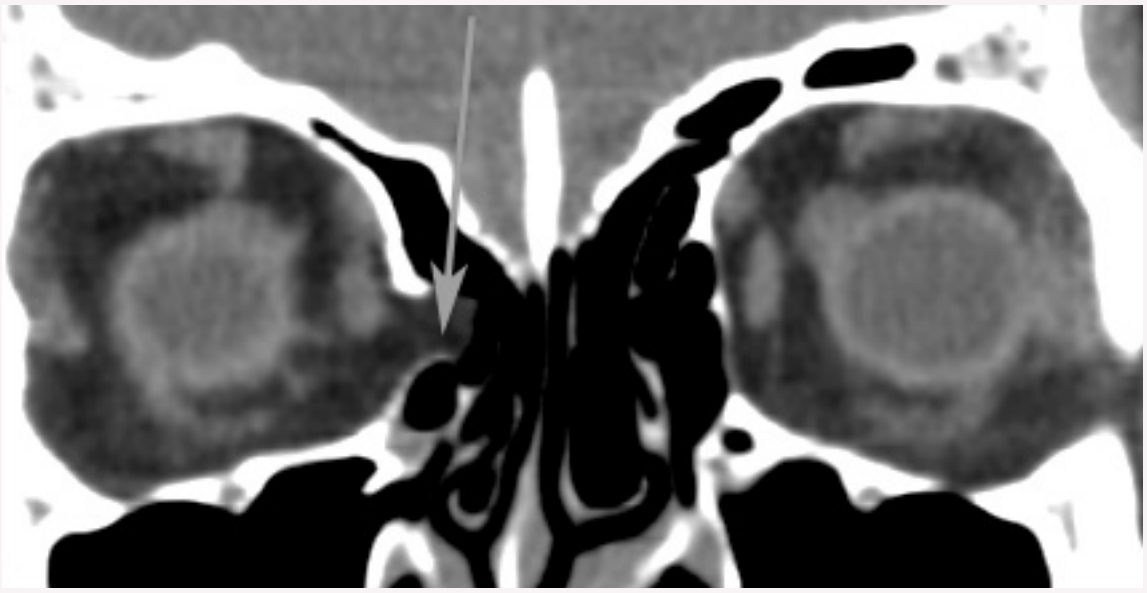


Image showing Coronal CT nose & sinuses bone window showing dehiscence of lamina papyracea (arrow).

Anterior Ethmoidal artery:

Anterior ethmoidal artery exits the orbit at the junction of medial rectus and superior oblique muscle and enters the nasal cavity at the roof of the ethmoid. Then it pierces the lateral lamella of the olfactory fossa to enter the intracranial cavity. Then it traverses along the ethmoidal sulcus anteriorly. It gives off a small artery to the falx cerebri termed as the falcine artery. The main artery traversing the ethmoidal sulcus of the olfactory fossa exits the fossa to enter the roof of the nasal cavity supplying that area of the nose while running in a groove along the deep surface of the nasal bone. Here is bifurcates into a medial and lateral branch. The lateral branch supplies blood to the lateral wall of the nasal cavity and a medial branch suppling the nasal septum. A terminal branch of this lateral branch called the external nasal branch passes between the nasal bone and the nasal cartilage to supply the skin of the nose. Once the anterior ethmoidal artery is visualized in the cut then it could be safely assumed that the cut has reached the level of basal lamella. If anterior ethmoidal artery is naked then it is always associated with supraorbital pneumatization.

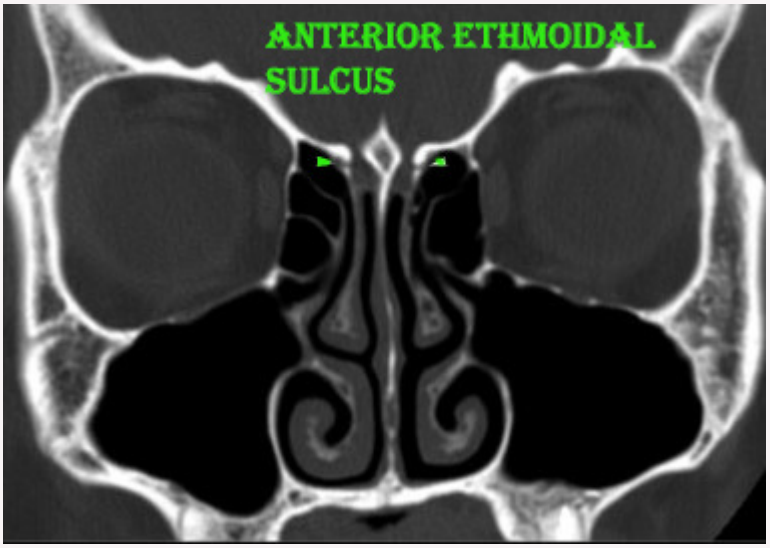


Image of coronal CT of nose and sinuses showing anterior ethmoidal sulcus on the lateral walls of the olfactory fossae. Anterior ethmoidal artery traverses this sulcus.

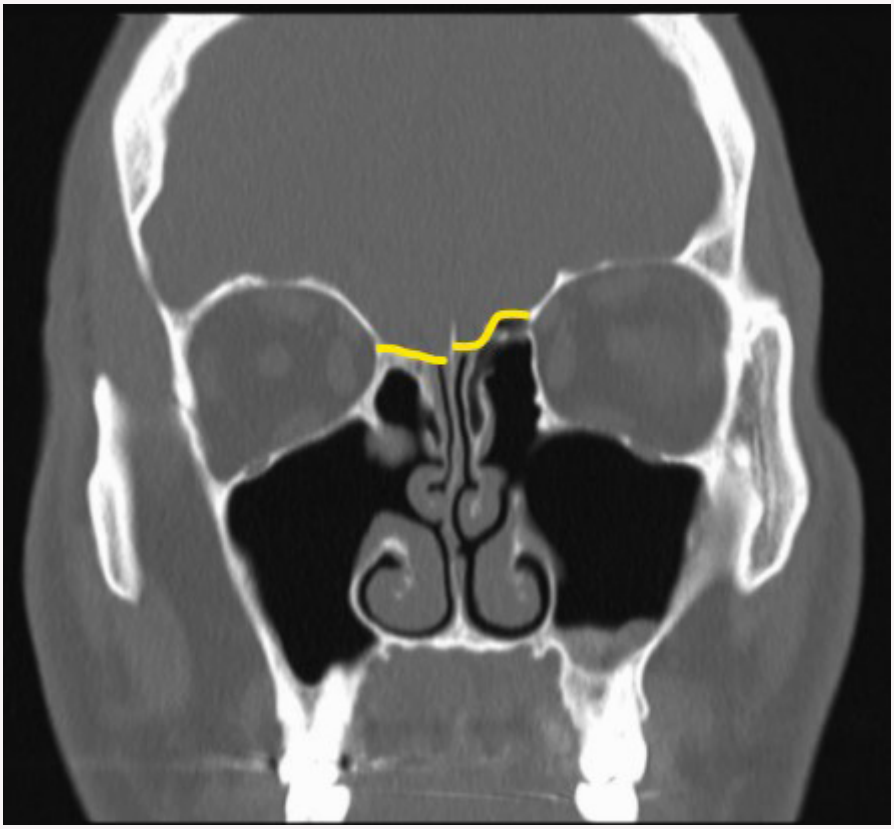


Image showing coronal CT nose and sinuses showing right skull base lower than that of the left side (marked in yellow). This condition is known as asymmetry of skull base. This condition should be identified from CT images taken prior to surgery. Surgeon should assess the level of anterior skull base and asymmetry between sides if any should also be taken into consideration. Surgeon who has not seen the CT images prior to surgery would risk breaching anterior cranial fossa on the side where the skull base is at a slightly lower level. Prior knowledge of this condition will help in preventing this complication.

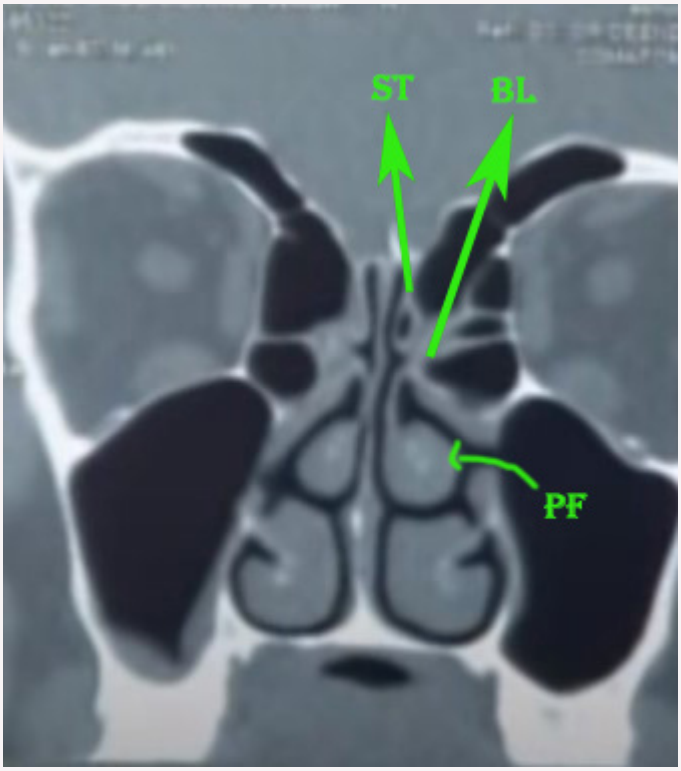


Image showing Coronal section of CT nose and sinuses. Note:

ST - Superior turbinate attached to skull base

BL - Basal lamella (horizontal portion of middle turbinate)

PF - Posterior fontanelle since it is situated behind the uncinate process

It should be noted that the superior turbinate gets attached to the skull base and the area of attachment is thick hence there is very minimal risk of breach of skull base of the superior turbinate is manipulated.

The anterior ethmoidal cells are separated from the posterior ethmoid air cells by the basal lamella. The anterior ethmoidal cells are small in size and are large in numbers while the posterior ethmoidal cells are larger in size and fewer in number. The skull base over the posterior ethmoidal air cells appears thicker and is also horizontal.

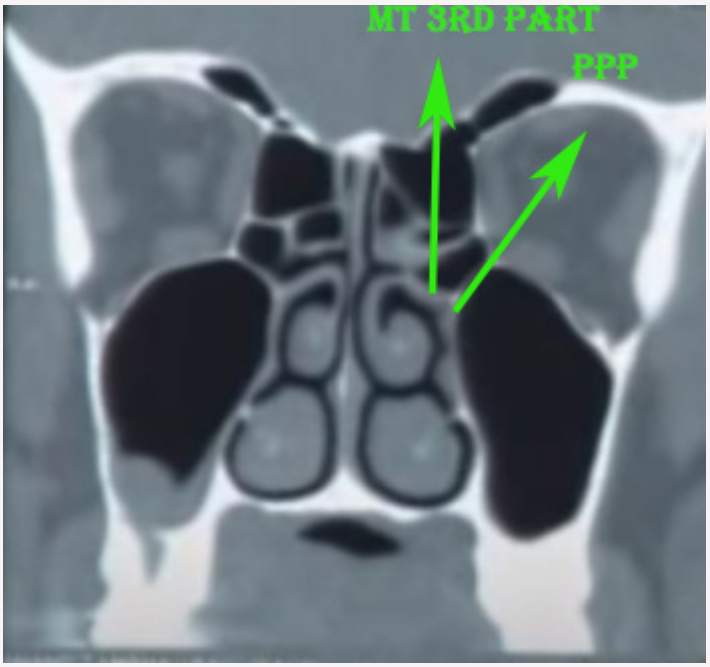


Image showing Coronal CT of nose and sinuses

MT - Middle turbinate

PPP - Perpendicular plate of palatine bone

Third part of middle turbinate curves laterally and gets attached to the perpendicular plate of palatine bone which forms the posterior portion of the medial wall of maxillary sinus. This portion of the medial wall of maxillary sinus is really thick. Note maxillary sinus gets more or less oval in cuts where posterior ethmoids are visible. This change in shape of maxillary sinus to oval is a good indicator of the location of the cut (posterior ethmoids).

Ct scan changes when one goes from anterior to posterior ethmoids:

1. Size of the orbit becomes smaller

2. Maxillary sinus becomes more oval

3. Skull base shows flatter roof of posterior ethmoid. It is thicker

4. Posterior ethmoid artery could be seen traversing along the skull base lining the posterior ethmoid air cells. This part of the skull base is really thick.

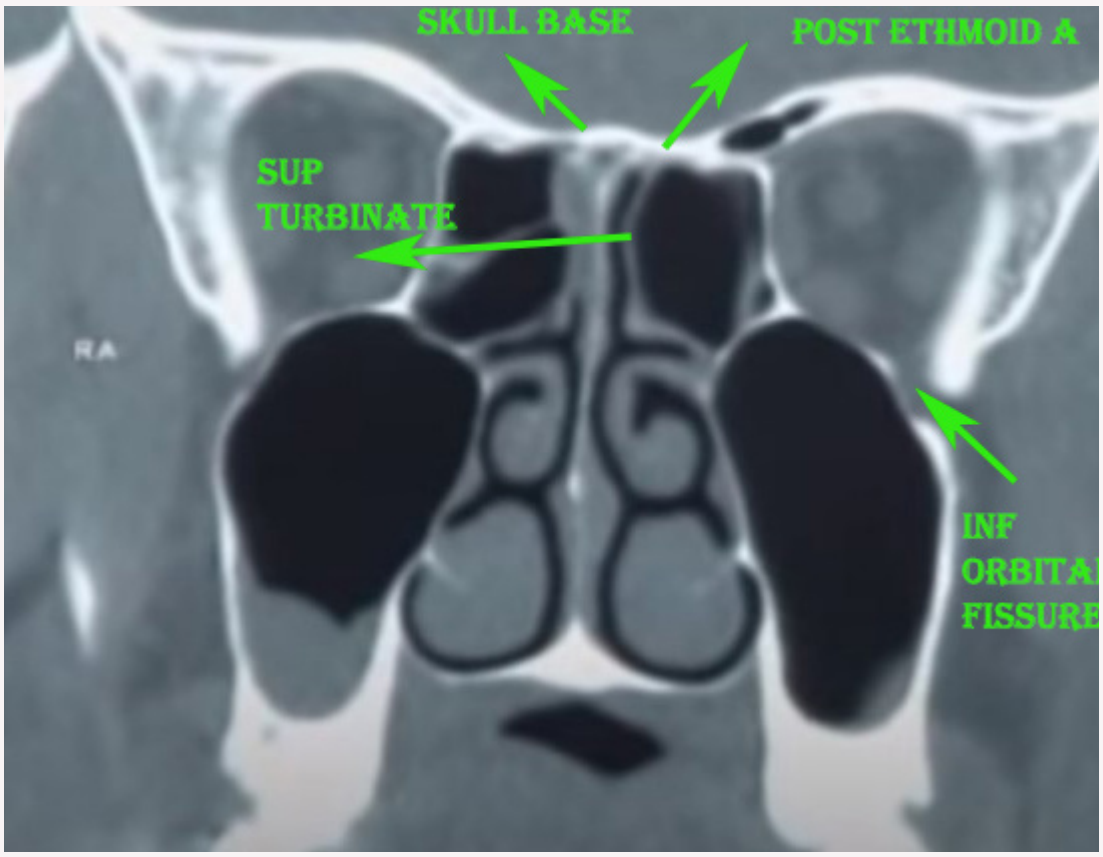


Image showing coronal CT nose and sinuses taken at the level of posterior ethmoidal air cells.

Note the large sized posterior ethmoid air cells (fewer in number). Skull base over the posterior ethmoid air cells is thick and horizontal. Infraorbital fissure is also clearly seen. Superior turbinate is also clearly seen and it forms the medial boundary of posterior ethmoidal air cells. In this cut posterior ethmoidal artery could be seen traversing the roof of the posterior ethmoid air cells. The begining of the posterior ethmoid is marked by superior turbinate.

As long as one sees the complete extent of nasal septum in the coronal cuts the slice is from the posterior ethmoid air cells. When the nasal septum becomes incomplete then sphenoid sinus comes into view.

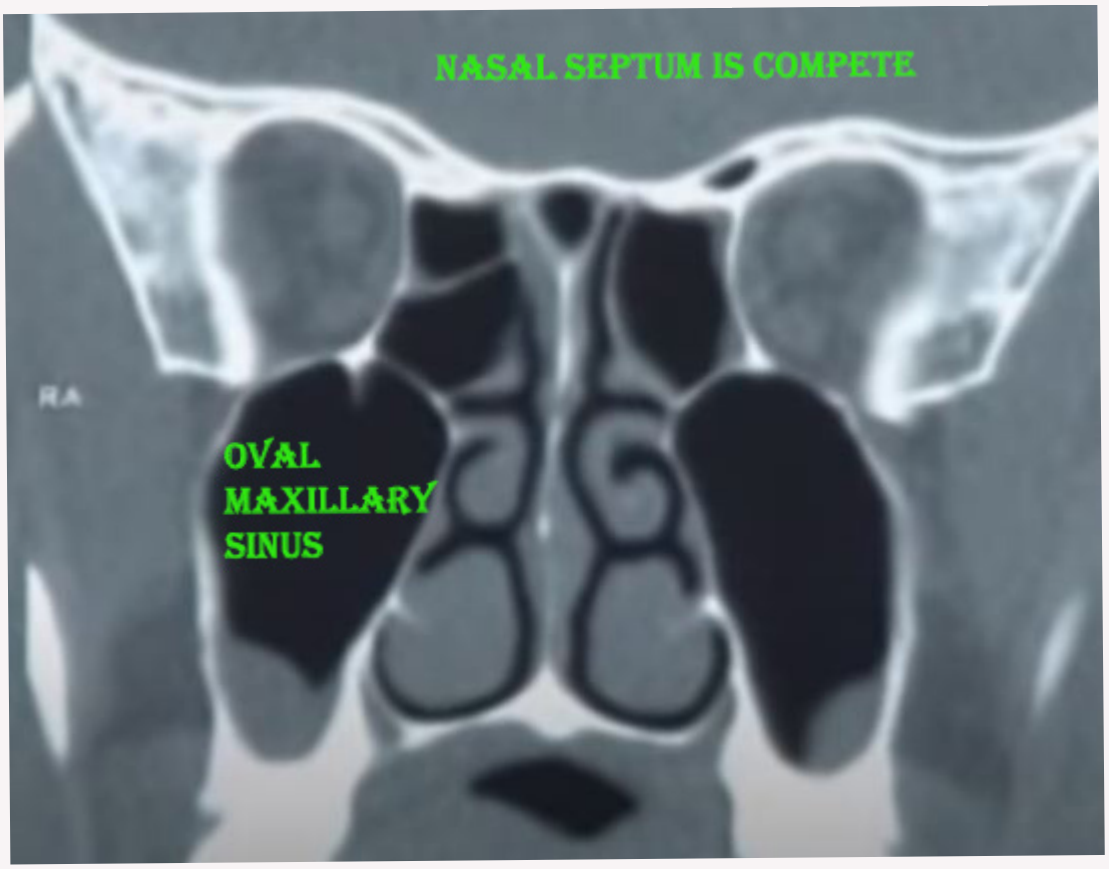


Image showing coronal CT of nose and sinuses taken at the level of posterior ethmoid air cells. Note the nasal septum is completely visible and the maxillary sinus has taken an oval shape. These two features help us to determine the level of the coronal cut.

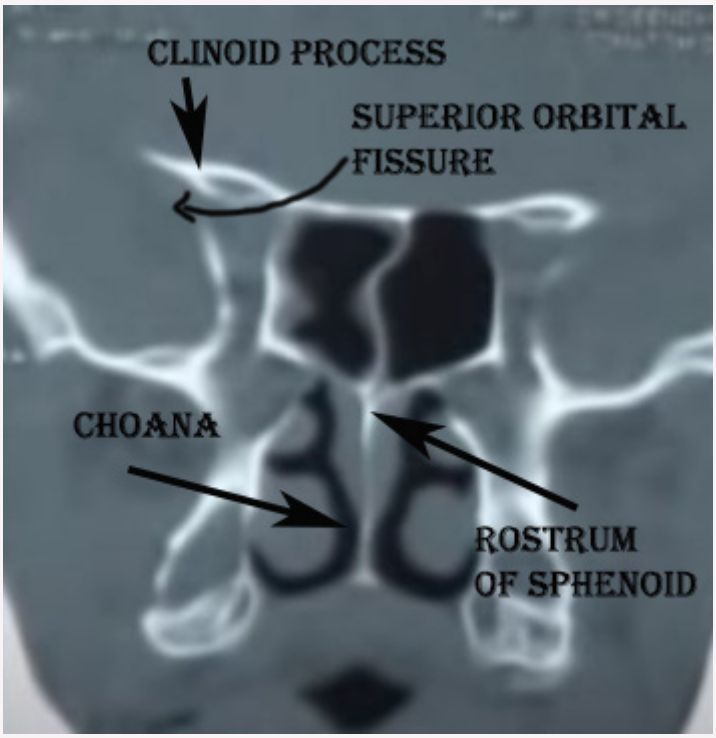
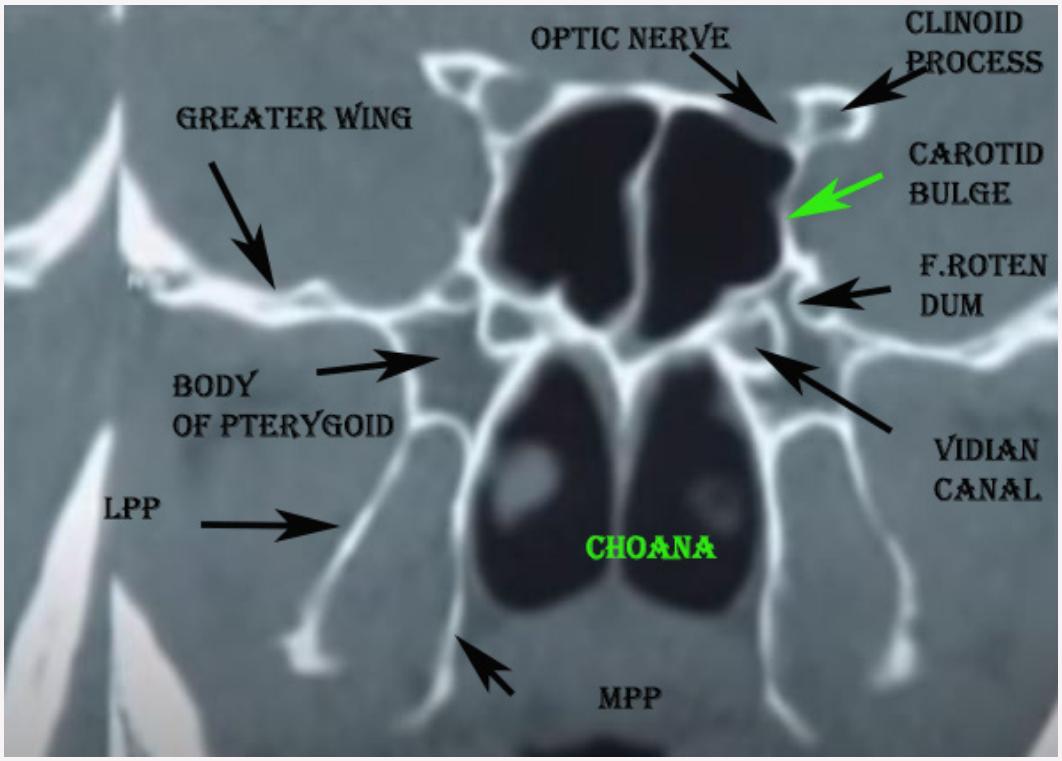


Image showing coronal cut of CT nose and sinuses showing sphenoid sinus. The nasal septum is not completely visible. In all other previous cuts nasal septum would be fully visible. In sphenoid cuts nasal septum is only partially visible. Rostrum of sphenoid the posterior most portion of nasal septum is seen. Rostrum of sphenoid is the only midline component of the nasal septum. Choana along with the posterior ends of middle and inferior turbinates are also visible. Clinoid process and superior orbital fissure are also clearly shown as marked in this image. It should also be appreciated that from this cut onwards the only bony structure that is visible is the sphenoid bone along with its various foramen unlike the previous cuts where other bones too are visible.



In this cut the sphenoid sinus cavity is clearly visible along with the intersphenoid septum which divides the sinus cavity into two. Medial to the clinoid process lie the optic nerve bulge and below it lies the carotid bulge. In well pneumatized sphenoid bones there will be a recess between these two bulges known as the carotico-optical recess. The body of pteryoid process along with the medial and lateral pterygoid plates (MPP and LPP) are also seen. Greater wing of sphenoid is also visible in this cut. In this image the pterygoid body is not well pneumatized and hence the vidian canal and foramen rotendum are seen along the floor of the sphenoid sinus. In some patients the pterygoid body will be well pneumatized and this condition is known as lateral sphenoid recess. In the presence of lateral sphenoid recess the vidian canal and foramen rotendum could loose their bony covering causing their structures to lie naked in the floor of the frontal sinus.

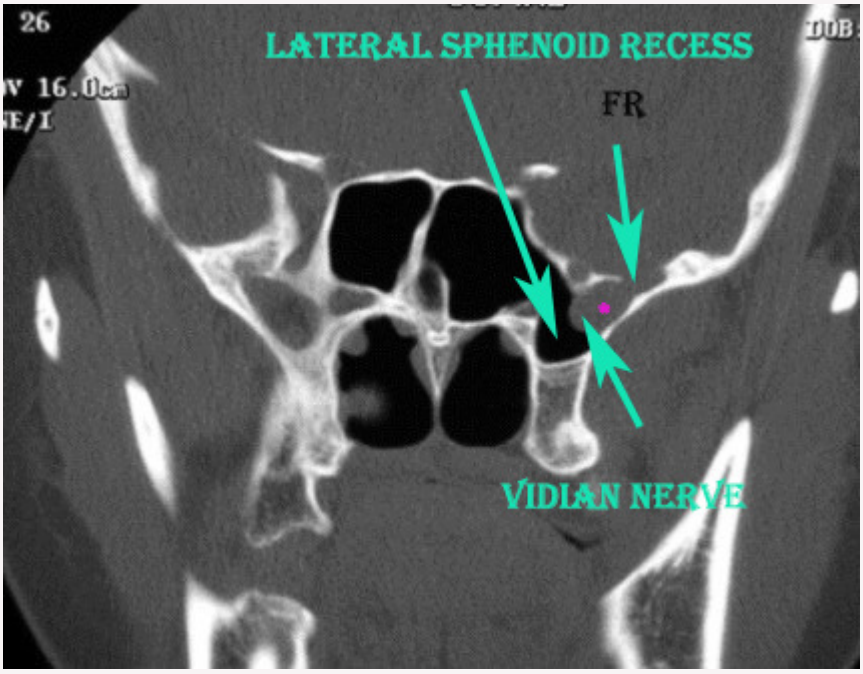


Image showing coronal CT of nose and sinuses sphenoid cut. Sphenoid sinus pneumatization appears to extend inferolaterally into the body of pterygoid. This is known as lateral sphenoid recess. Vidian nerve is found to lie naked in the floor of the sphenoid sinus. Foramen rotendum is marked with a green arrow lateral to the vidian nerve.

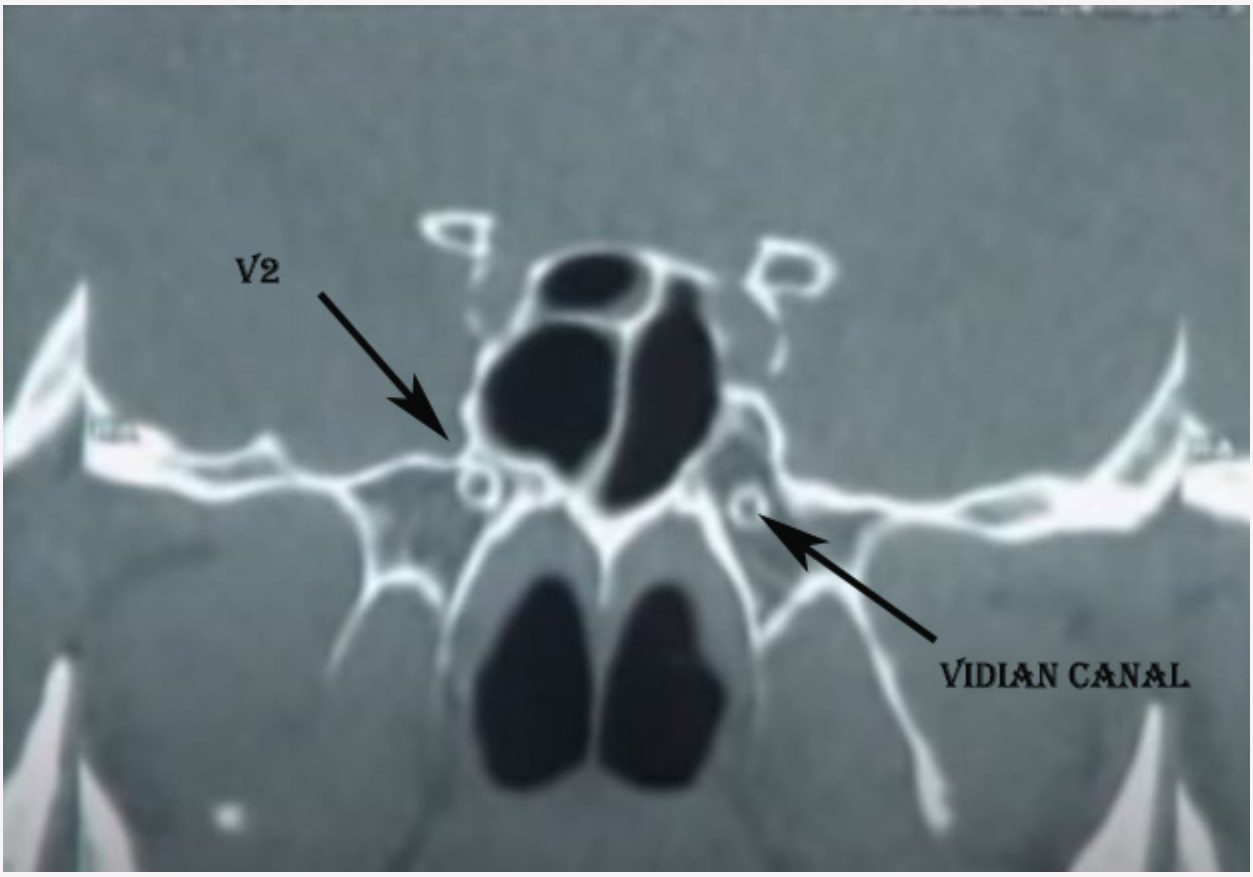


Image showing coronal CT nose and sinuses. In this cut vidian canal is clearly seen in the pterygoid body close to the floor of the sphenoid sinus. This isa very important landmark to indentify foramen lacerum and carotid artery during skull base surgeries. V2 is foramen rotundum through which the second branch of trigeminal nerve passes through. Foramen ovale is found lateral to V2 and is not visible in this cut. This foramen is ideally viewed in axial sections of CT nose and paranasal sinuses.

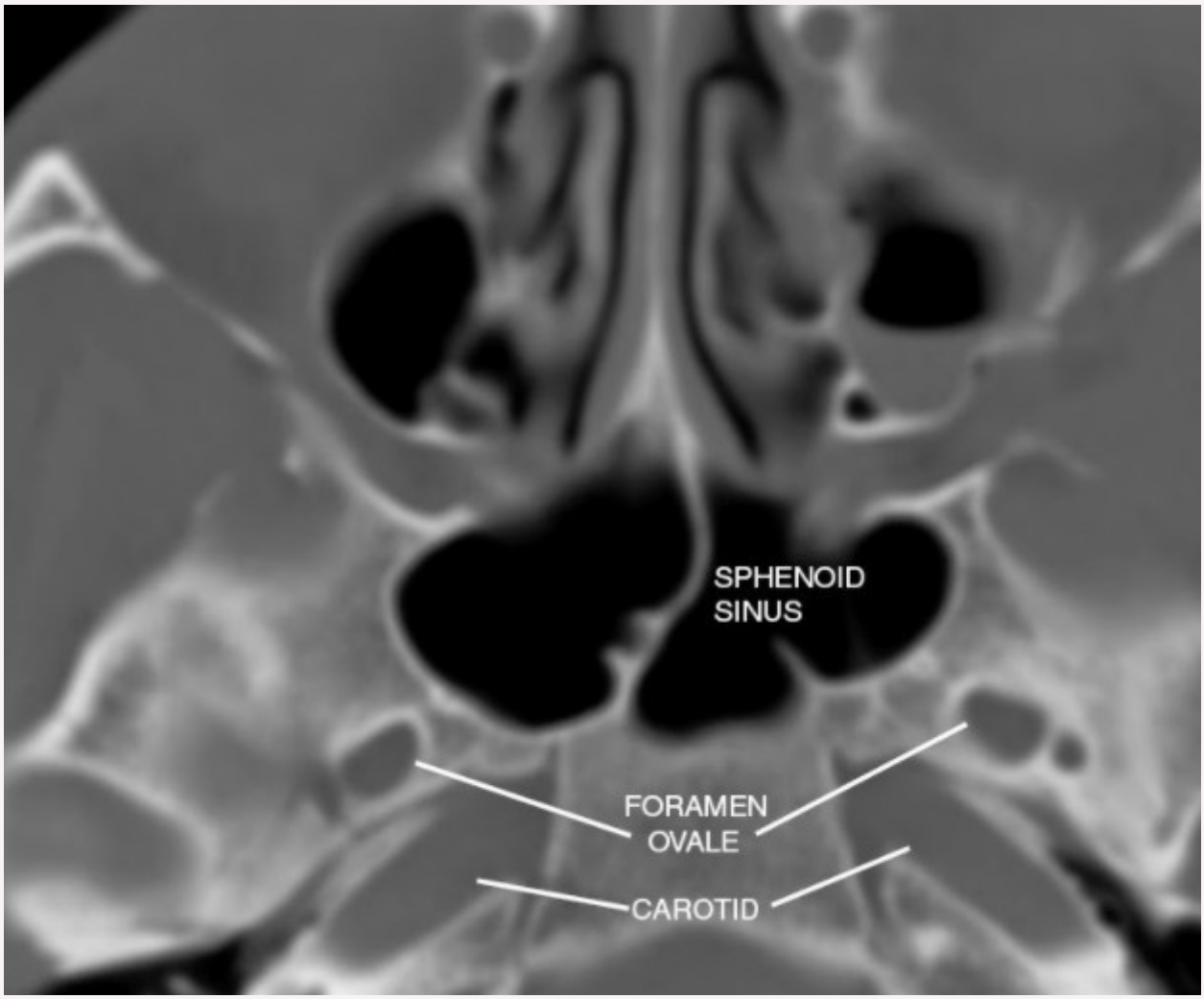


Image showing CT sinuses axial cut taken at the same level as the previous coronal section showing foramen ovale, and carotid artery lying close to foramen lacerum. Foramen oval is ideally well seen in axial sections.

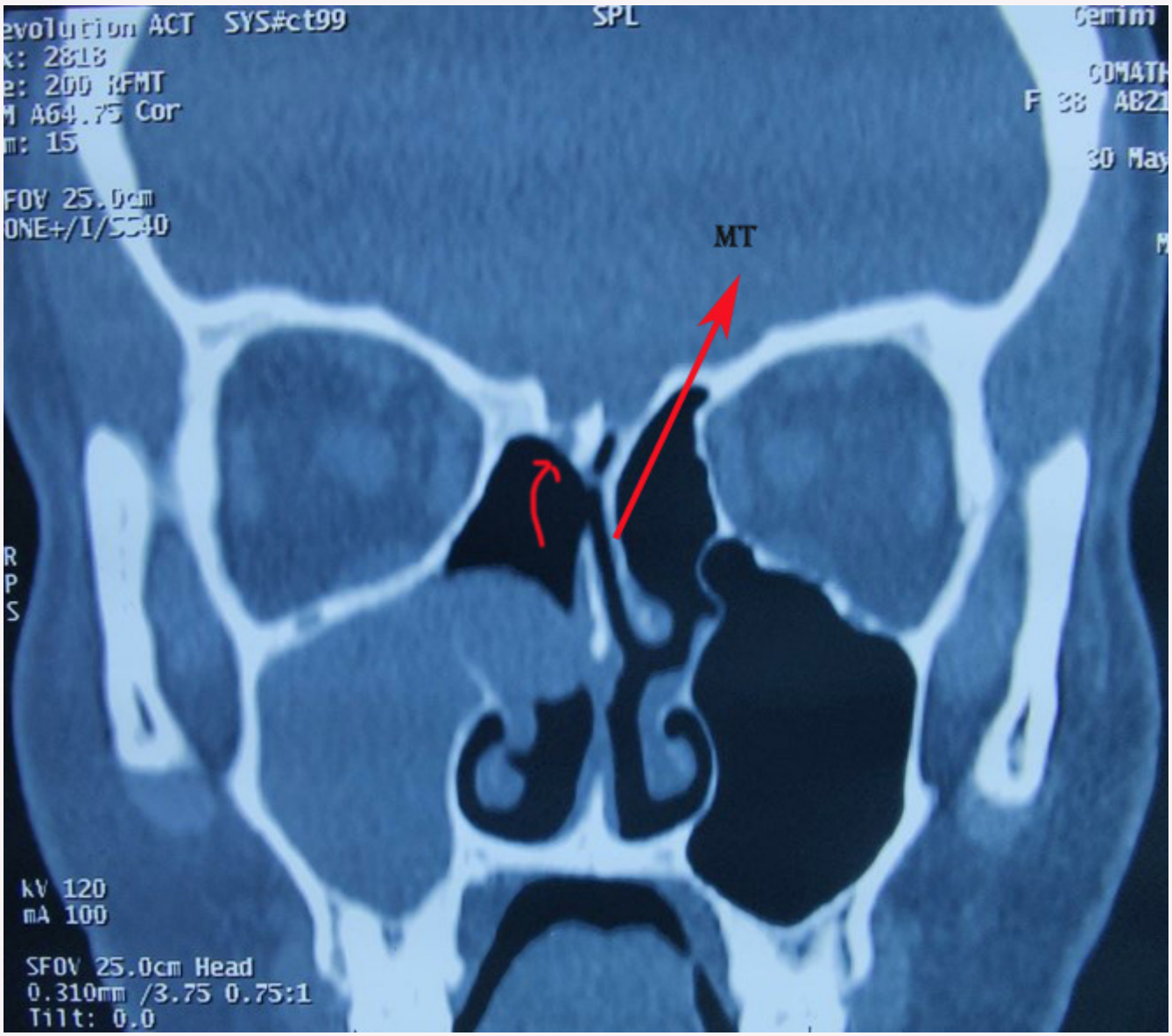


Image showing Coronal CT of nose and sinuses of a patient with iatrogenic CSF rhinorrhoea following FESS surgery. Note the defect in the skull base in the olfactory fossa area (red curved arrow). Middle turbinate is absent on the right side probably resected during the surgical procedure. Surgeons should be warned about the fact that the skull base attachment of middle turbiante is rather friable as it gets attached to the lateral lamella of the olfactory fossa. This portion of the skull base is paper thin and rather weak. Manipulation of the middle turbinate forcibly can cause disruption in this area causing CSF leak. Ideally middle turbinate should be saved during the process of FESS as it not only serves as a valuable landmark to other vital intranasal structures, disrupting its superior attachment could cause CSF leak. Note the normal middle turbinate on the left side. Soft tissue mass could be seen filling the right maxillary antrum. The same mass could be seen exiting out of the maxillary sinus cavity through the widened accessory ostium. (probably it is a antronasal polyp).

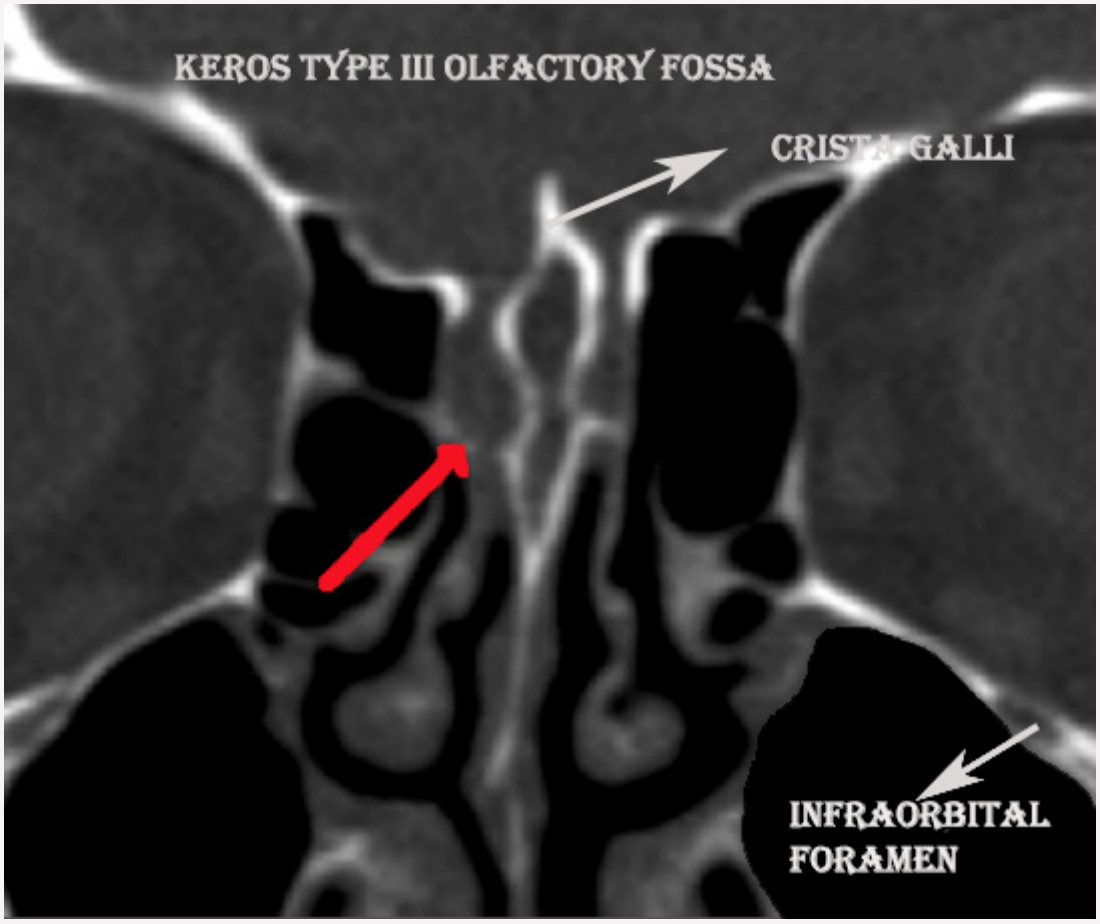


Image showing coronal CT of nose and sinuses showing a defect in the skull base close to the olfactory fossa. Red arrow points to the prolapse of intracranial contents into the nasal cavity. Olfactory fossa demonstrates Keros type III features.

Axial CT images of nose and paranasal sinuses Anatomy

Axial CT images of nose and paranasal sinuses should always be viewed in conjunction with that of coronal sections. Certain areas of nose and sinuses are best revealed in axial sections. Eustachean tube orifice, and fossa of Rosemuller are clearly seen in these images. Pterygoid plates and pterygopalatine fossa is also clearly seen. The initial focus of this chapter will be the study of anatomy of nose and sinuses as revealed in axial cuts.

Infundibulum of the osteomeatal complex is not clearly seen in coronal sections but is clearly seen in axial images. Entire osteomeatal complex can be clearly demonstrated in axial sections. Orbit is also clearly seen. The entire antero-posterior sections of orbit is fully visible in these sections. In studying septal deviations the entire extent of the nasal septum is clearly visible in these sections. Similarly the posterior ethmoid group of air cells are clearly visible in its entire extent. Onodi cell which is the posterior most of poserior ethmoidal air cells when present is clearly appreciated in this view. The critical relationship between the onodi cell and the optic nerve is also visible.

This view is very helpful in looking for involvement of posterior wall of maxilla in turmos involving the nose and sinuses. Tumors can erode the posterior wall of maxilla and extend into the pterygoplatine fossa. Involvement of pterygoid muscles by malignant tumors can also be clearly appreciated in this view.

While interpreting axial CT images they should always be compared with that of the corresponding coronal sections. This will ensure that the surgeon will get a clear understanding of the complex and variable anatomy of the region in addition to the accurate assessment of the extent of pathology.

In this chapter CT axial images of nose and sinuses would be arranged in a sequential order for easy understanding of the anatomy. Reader can view the anatomical structures as seen in axial sections.

Posterior wall of frontal sinus is clearly visible in these cuts. Frontal sinus study can never be considered to be complete without assessing axial cuts.

At times the coronal sections may contain radial blurring from the dental prosthesis / amalgams. In these areas axial images could solve this problem revealing the anatomy of the area better. Structures that are at right angle to the section plane are shown clearly while those that are parallel to the section plane are hard to identify. So structures that are parallel to the coronal plane are seen more clearly in the axial scan. Most of the structures that separate the paranasal sinuses like basal lamella and the anterior wall of sphenoid sinus are located in the coronal plane. These structures are better viewed on axial cuts.

Nasolacrimal duct, olfactory groove and optic nerve can be observed in both secctions. It is difficult to distinguish the difference between these two sections.

Even if a structure is easily observed in both scans, each scan shows a different portion of the structures because of their three dimensional quality. The following point could illustrate this example:

The ethmoid bulla's upper and lower walls appear in the coronal scan but its anterior and posterior walls are seen clearly in the axial scan. Anterior ethmoid artery is better seen in the coronal scan than in axial. Thinner sections (axial) 1 mm cuts should be taken to make anterior ethmoidal artery visible in axial cuts.

Image showing axial section of nose and sinuses showing anterior nasal spine

Axial sections cannot be used as a road map for endoscopic sinus surgery, but can be used for diagnostic purposes.

Uncinate process is clearly seen in coronal section. This section clearly demonstrates the type of superior attachment of uncinate process.

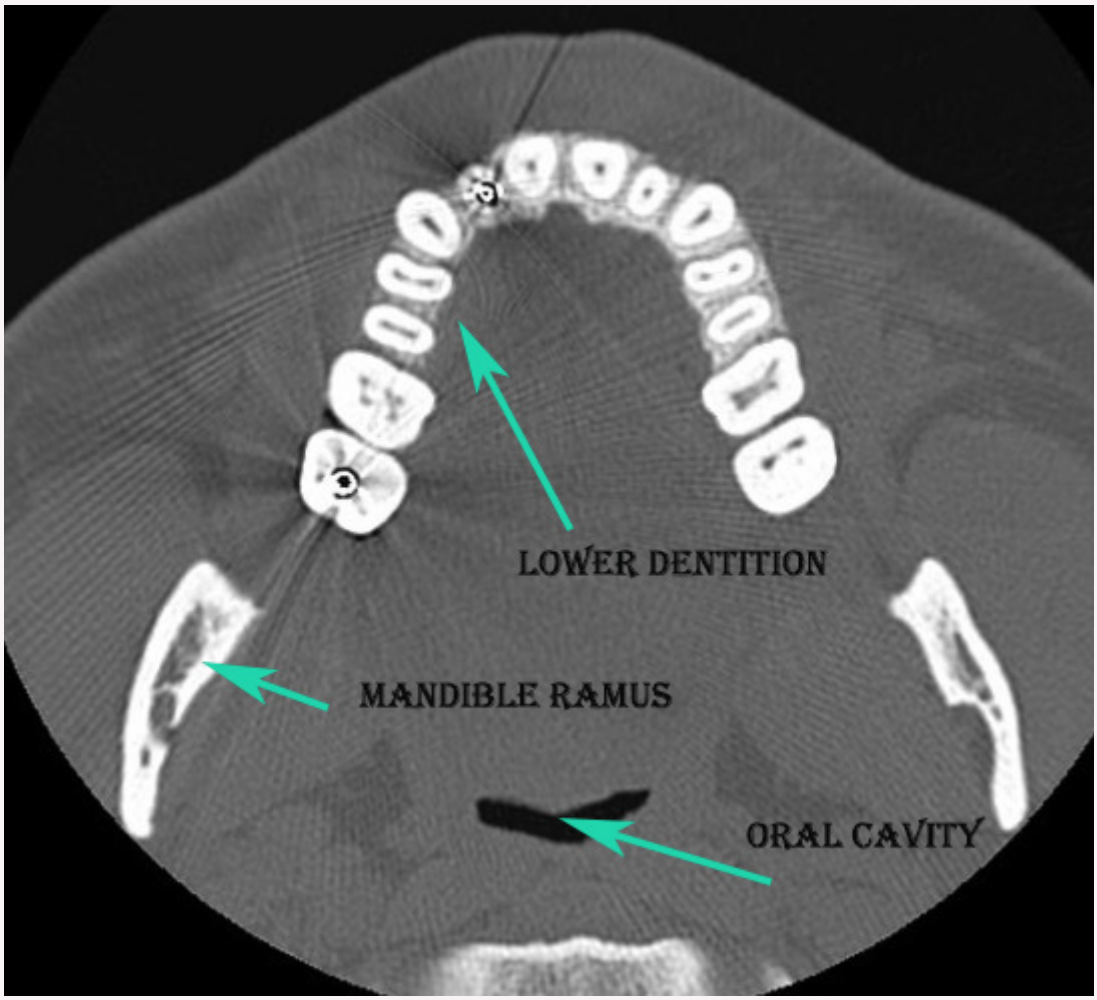


Image showing axial CT for nose and sinuse showing the ramus of mandible, oral cavity and lower dentition. Dental filling can also be clearly seen in this view if present.

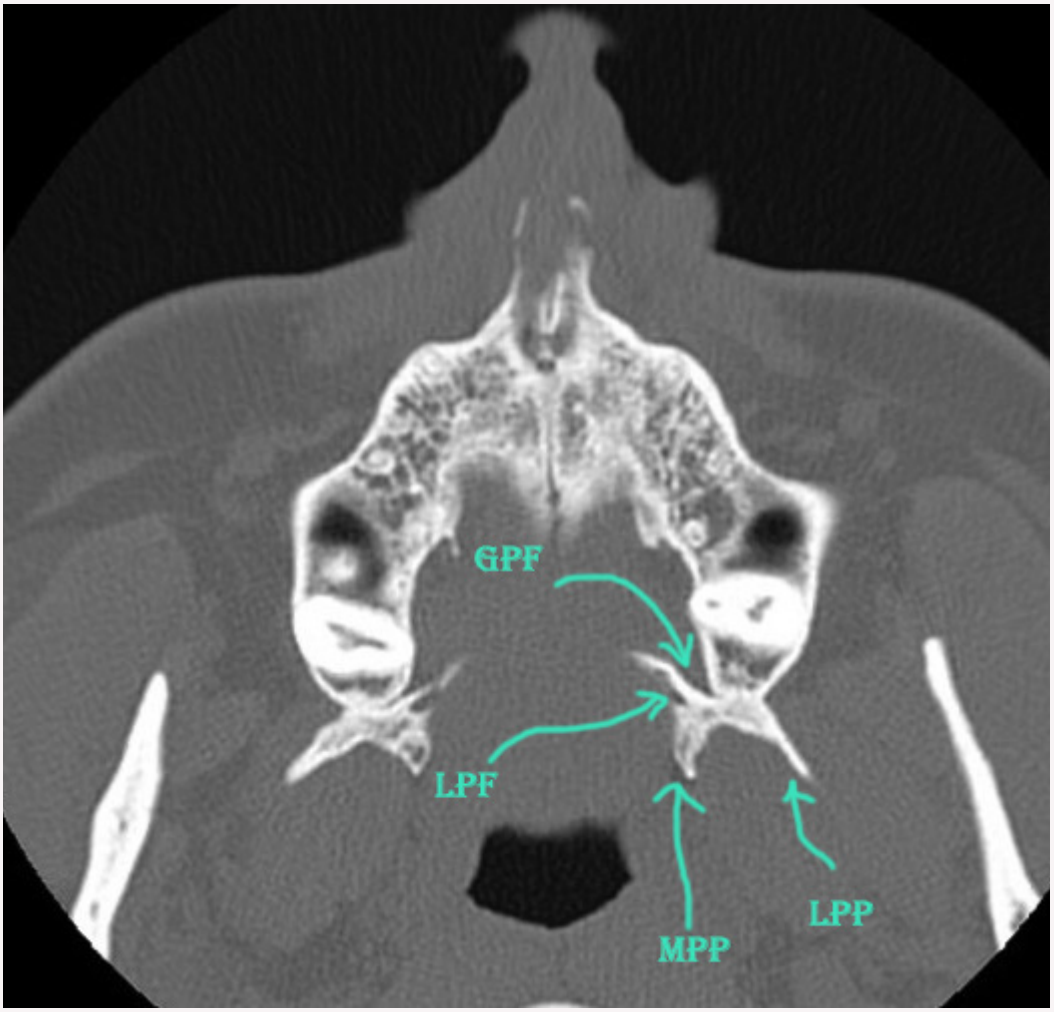


Image showing axial view of CT paranasal sinuses

GPF- Greater palatine foramen

LPP- Lesser palatine foramen

LPP - Lateral pterygoid plate

MPP - Medial pterygoid plate

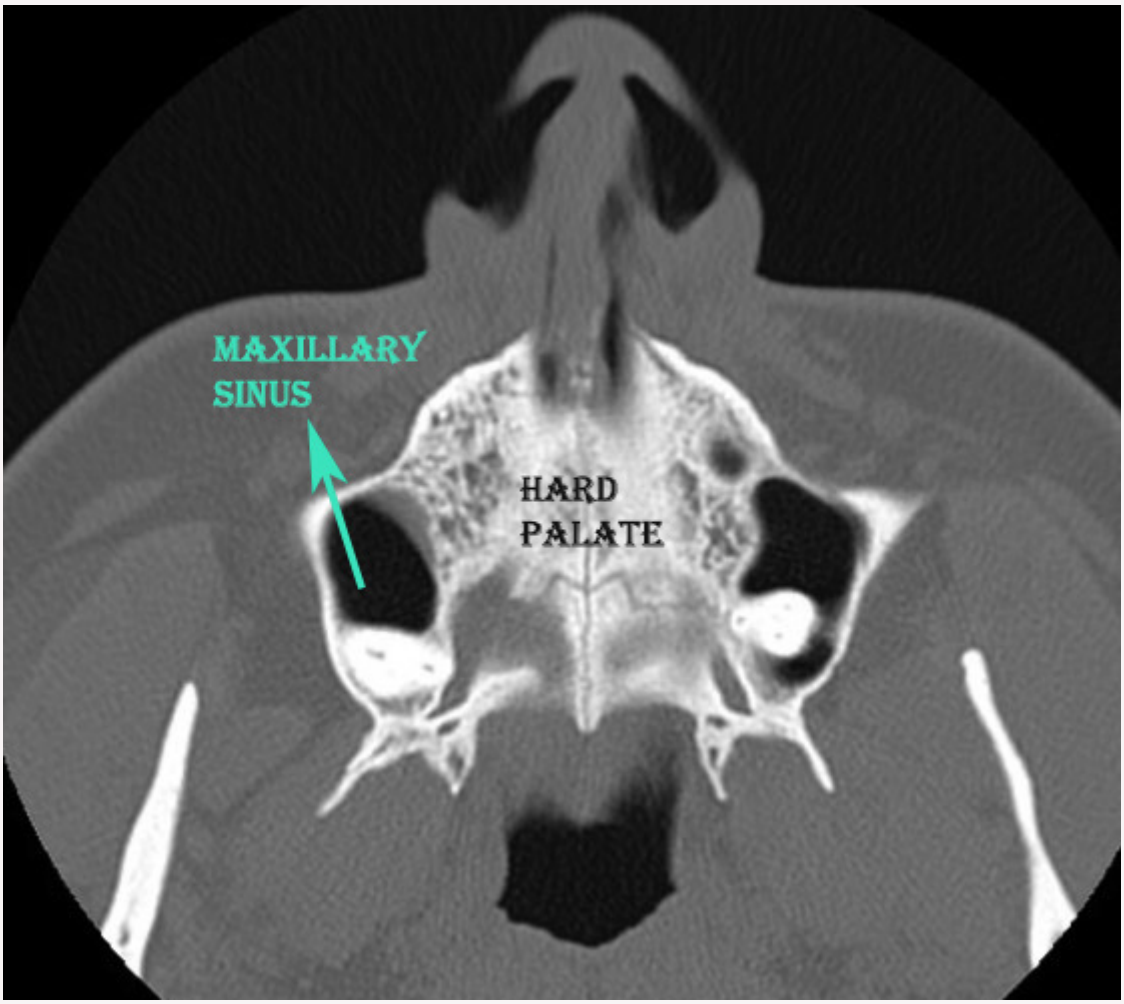
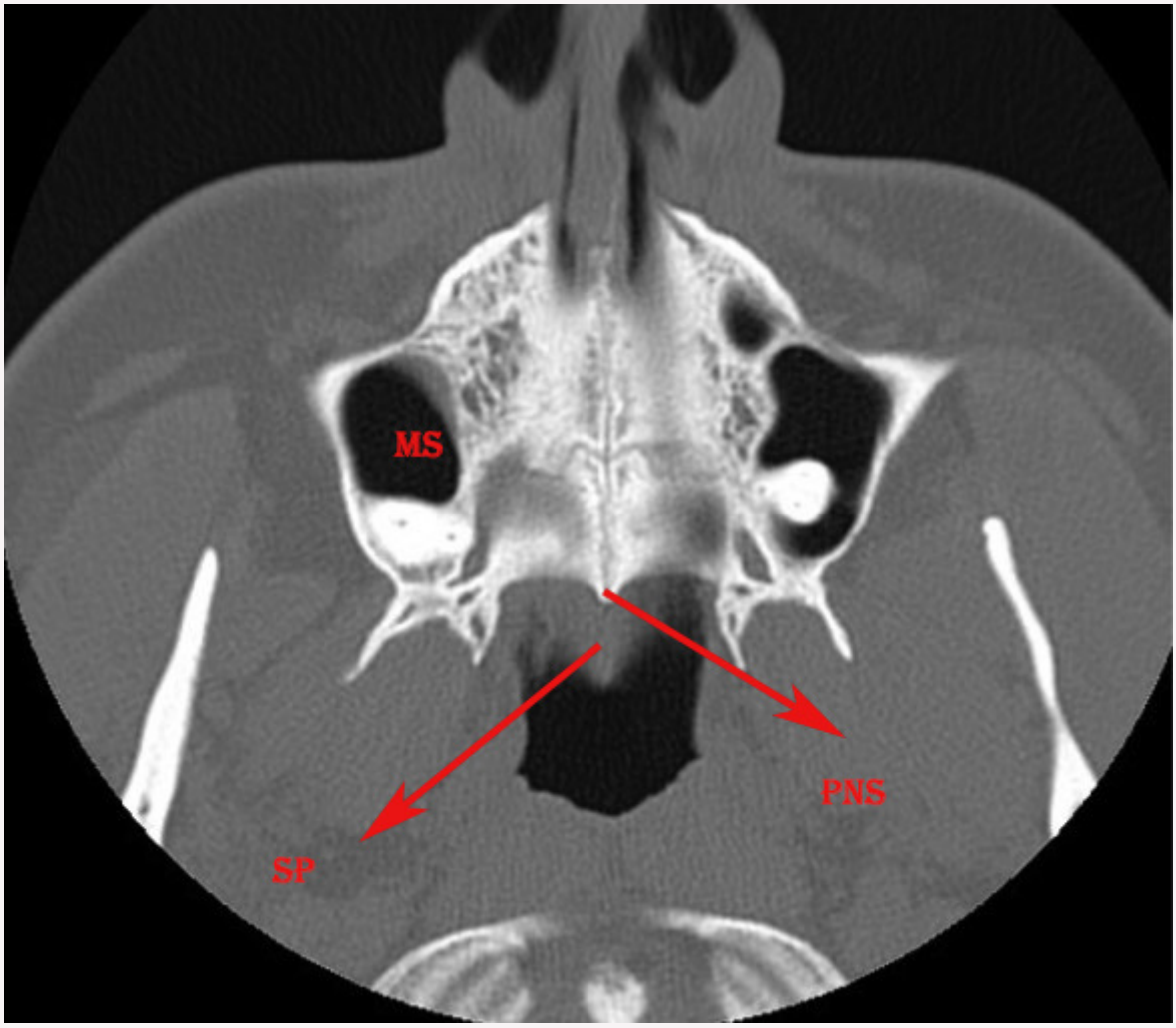


Image showing axial CT of nose and sinuses. This cut reveals maxillary sinuses on both sides. Molar teeth are visible. Hard palate is visiuble. Nasopharynx airway is visible.


MS
PNS
SP

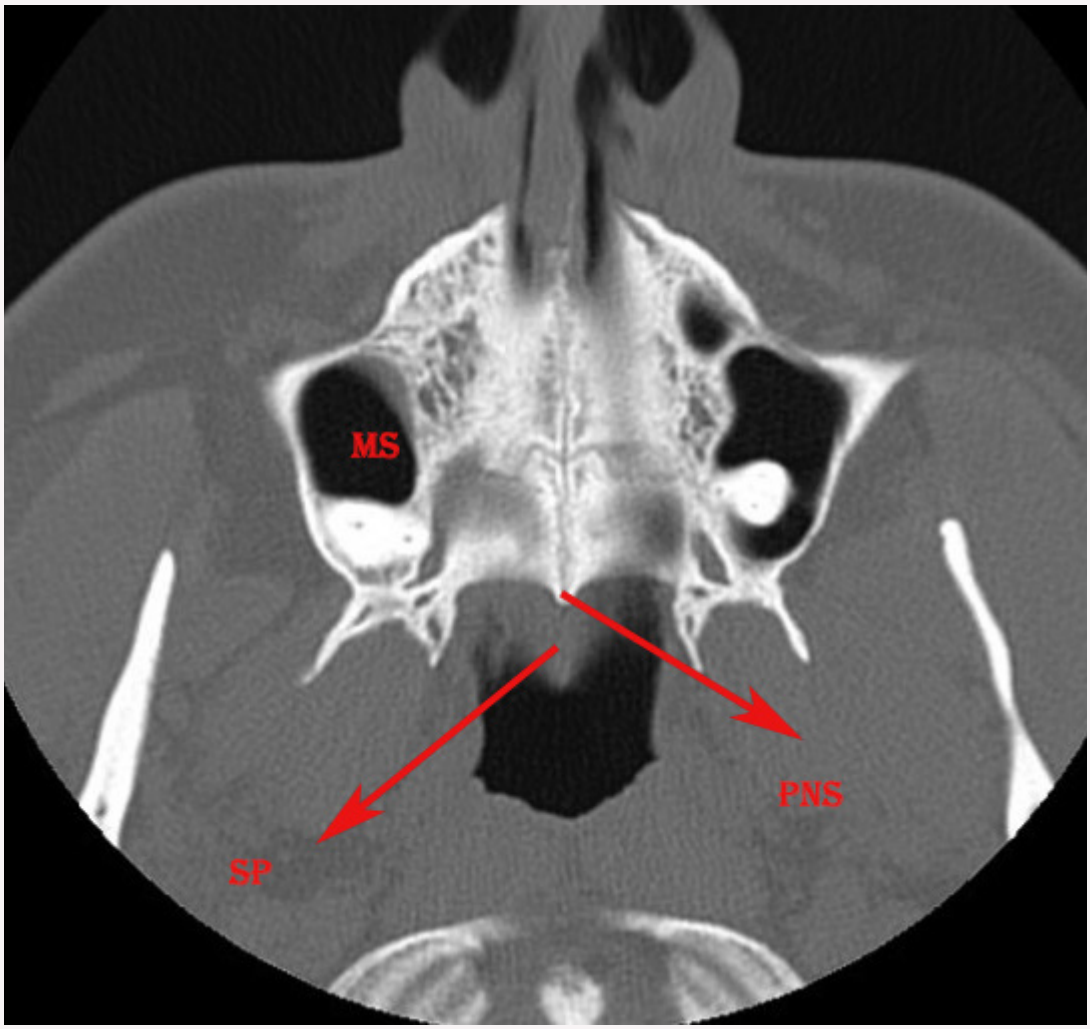


Image showing axial cut of CT nose and sinuses taken at the level of hard palate.

MS - Maxillary sinus

PNS - Posterior nasal spine

SP - Soft palate

Note- all the walls of maxillary sinus are visible in axial cuts

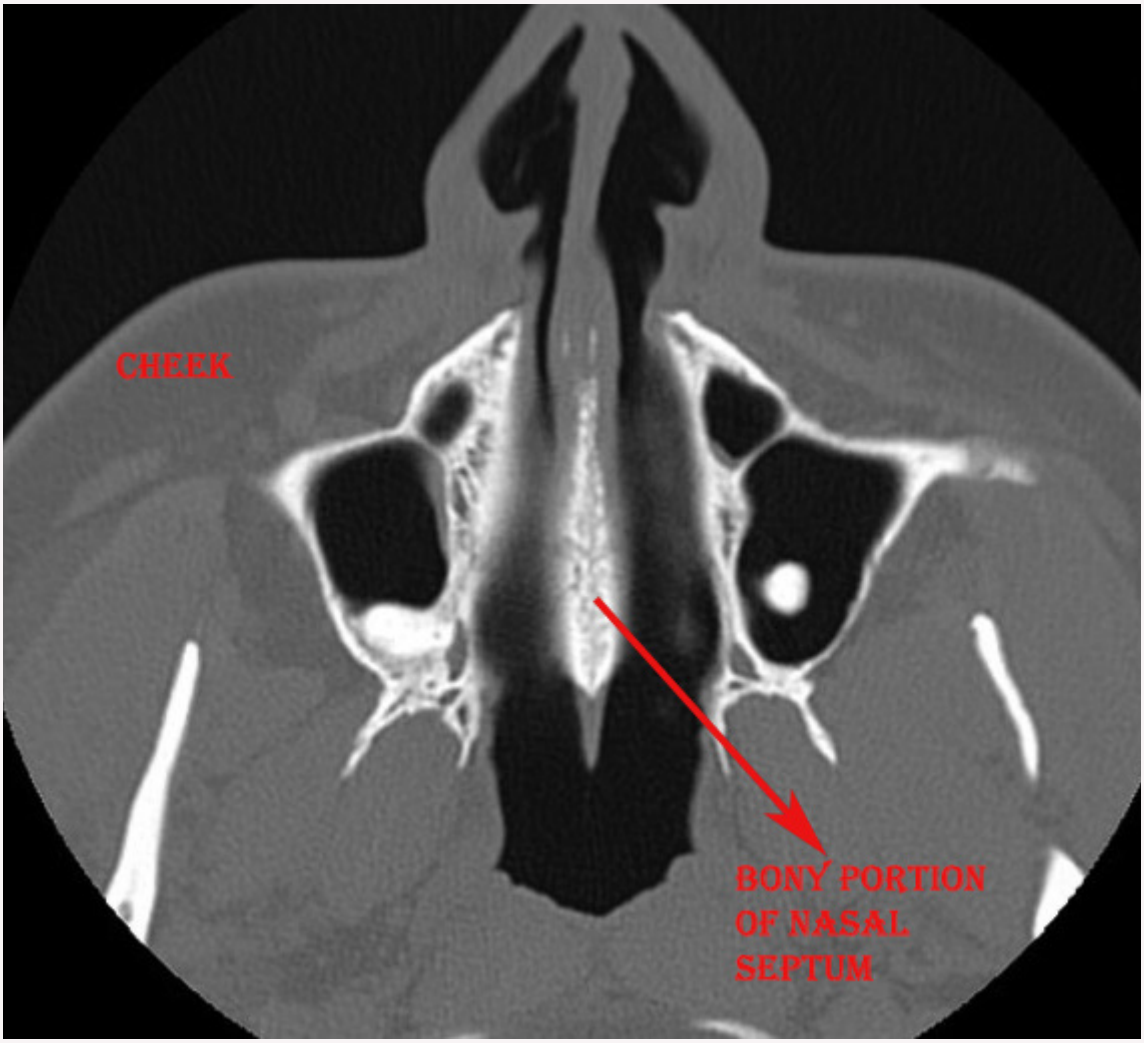


Image showing CT PNS axial section of nose and sinuses showing:

Bony portion of nasal septum

Unerupted molar teeth inside the maxillary sinus cavity

Nasal airway anteriorly

Nasopharyngeal airway posteriorly

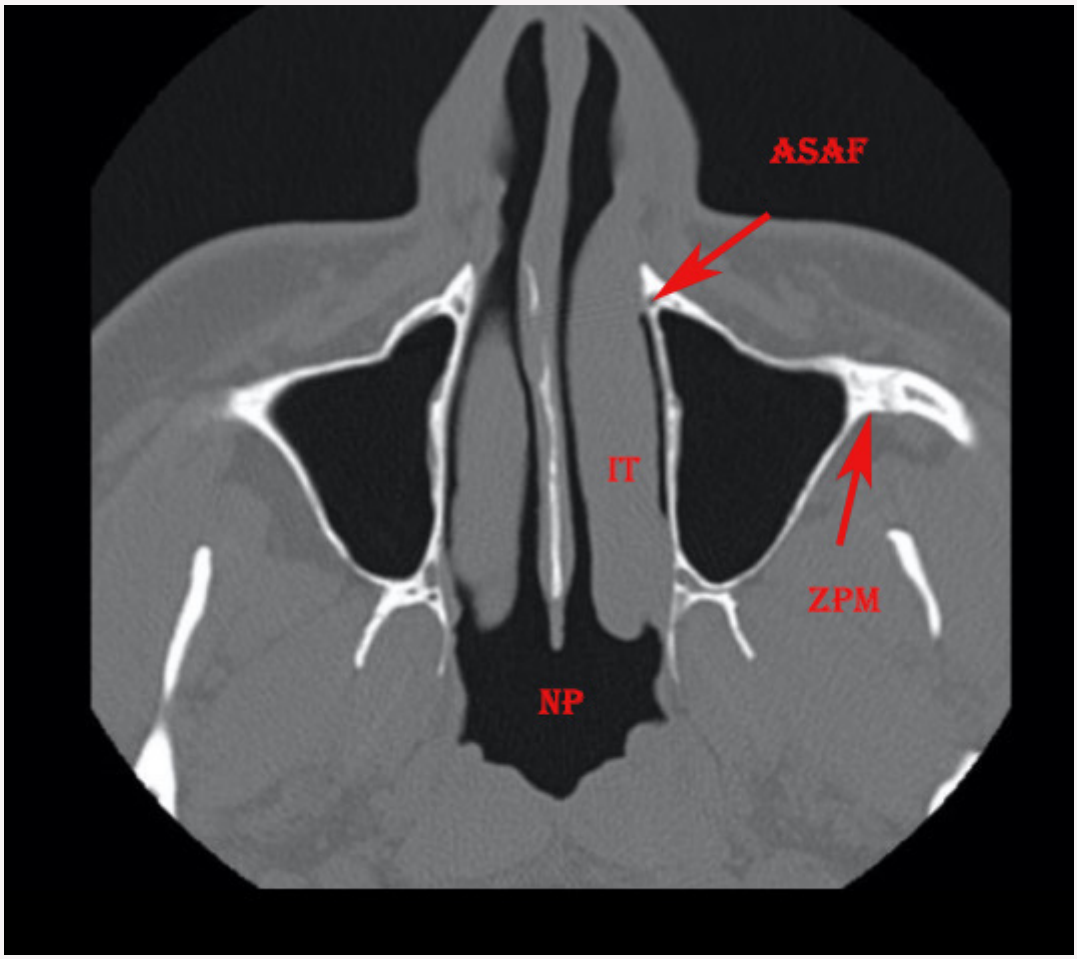


Image showing Axial CT of nose and sinuses

ASAF - Anterior superior alveolar foramen. This contains anterior superior alveolar nerve (anterior superior dental nerve). This nerve is a branch of infraorbital nerve which itselt is a branch of the maxillary division of trigeminal nerve. This nerve branches from the infraorbital nerve within the infraorbital canal before it exits through the infraorbital foramen. It descends in a canal in the anterior wall of maxillary sinus and divides into branches and supplies incisor and canine teeth.

ZP - Zygomatic process of maxilla

IT - Inferior turbinate

NP - Nasopharynx

Medial and lateral pterygoid plates are seen behind the maxillary sinus in this cut

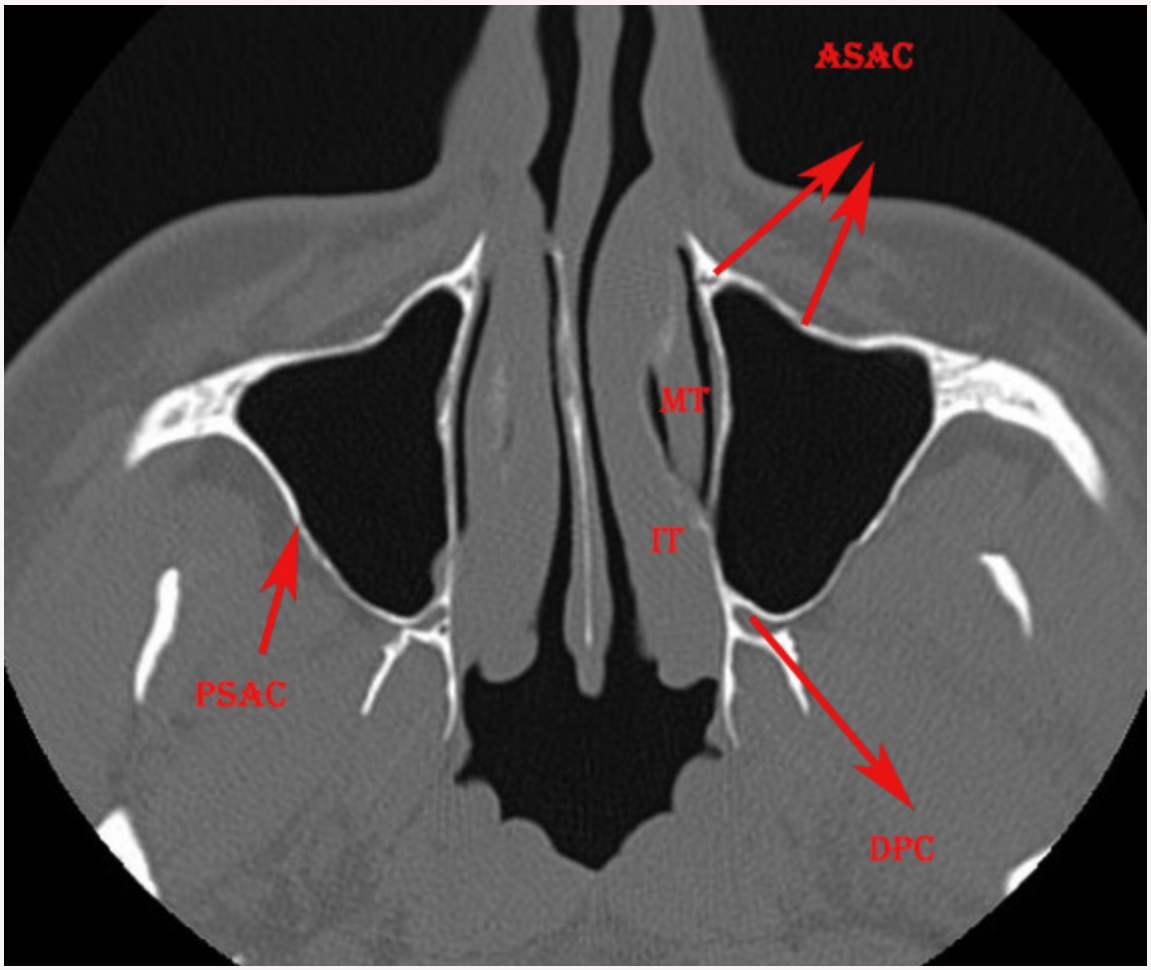


Image showing axial CT section of nose and sinuses. In this cut middle turbiante begins to be visualised.

ASAC - Anterior superior alveolar canals

MT - Middle turbinate

IT - Inferior turbinate

PSAC - Posterior superior alveolar canals

DPC - Descending pterygopalatine canal

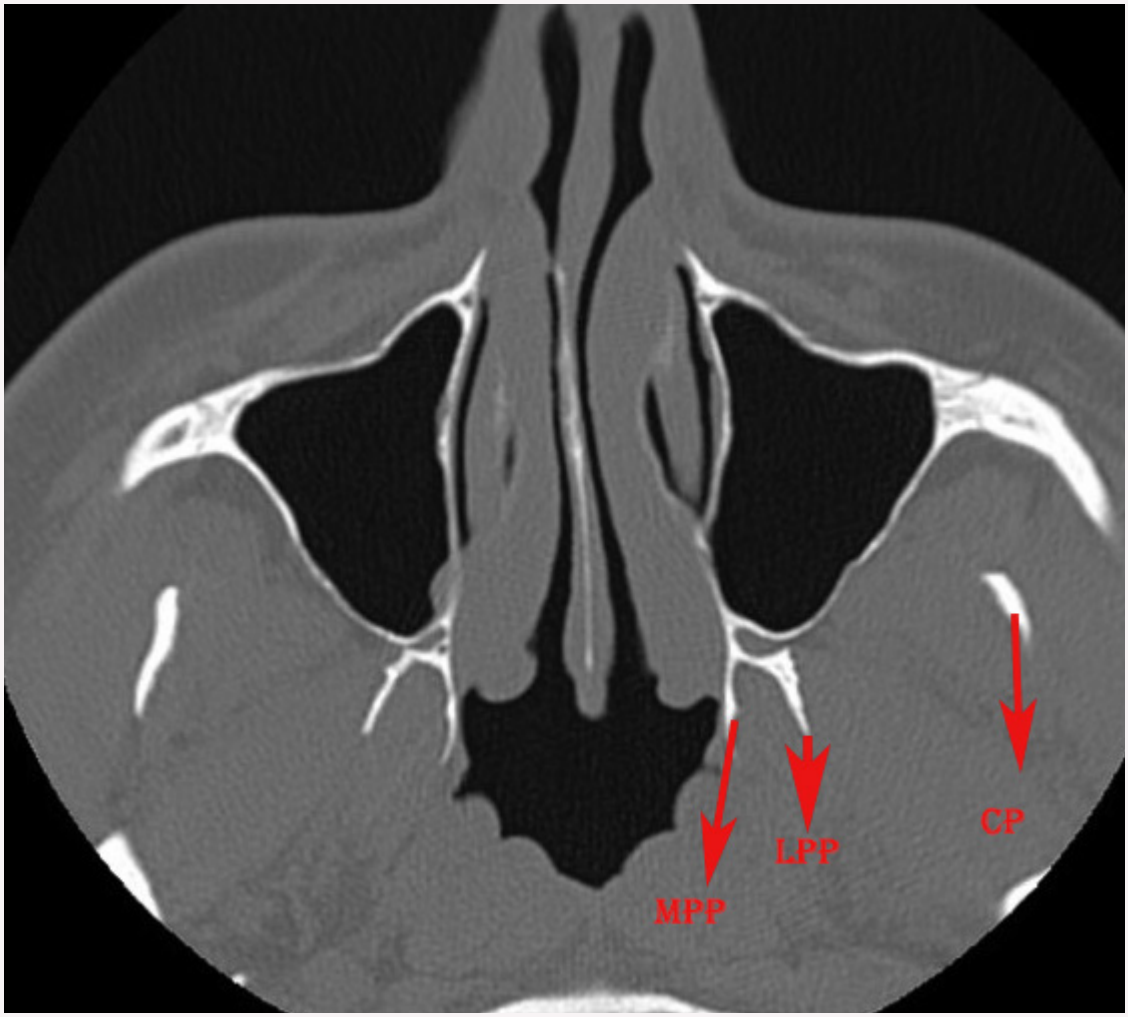


Image showing Axial cut CT PNS showing

CP - Coronoid process

LPP - Lateral pterygoid plate

MPP - Medial pterygoid plate

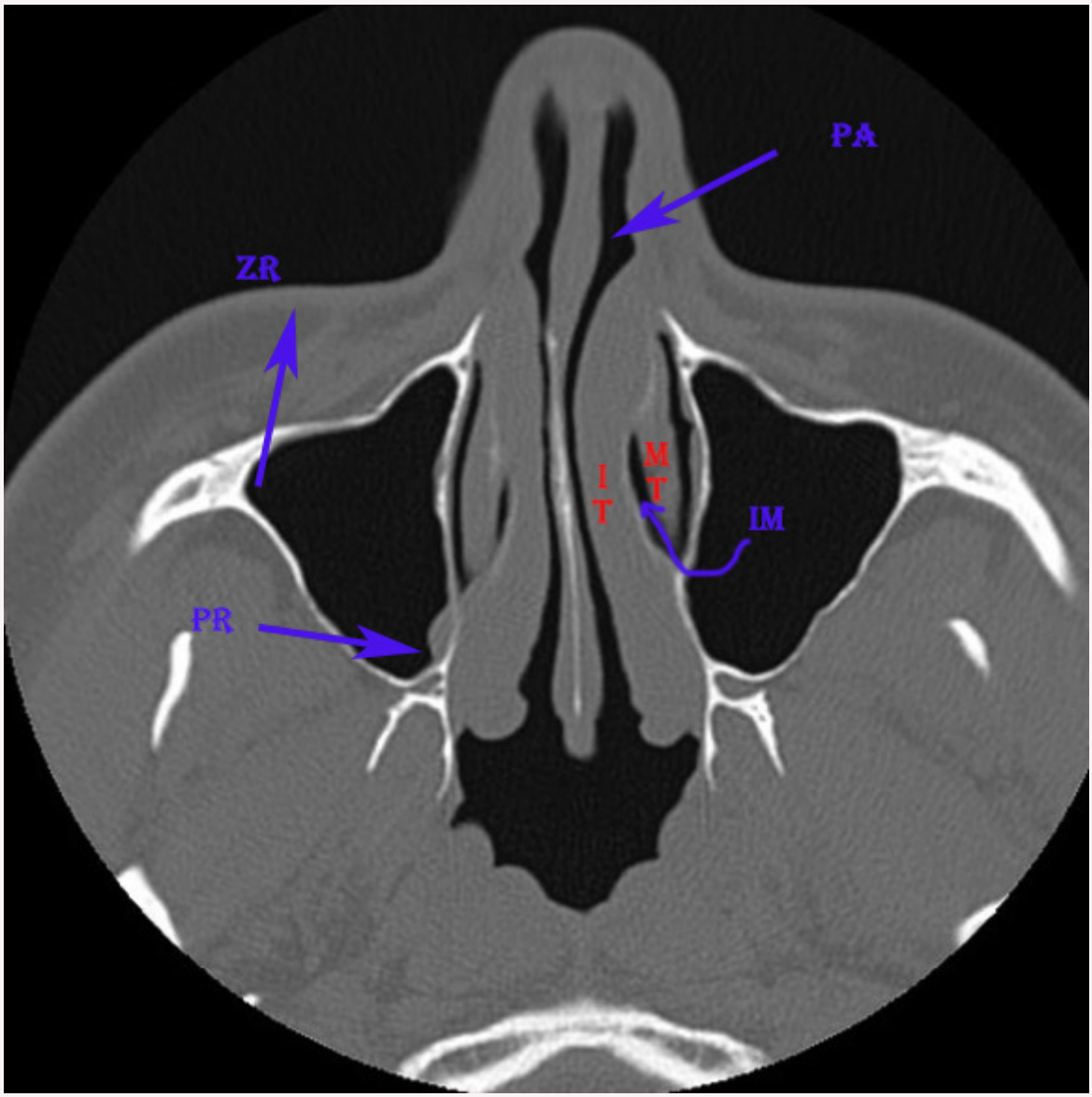


Image showing various structures of nose and sinuses revealed in axial CT cut taken at this level

PA - Pyriform aperture of nose

ZR - Zygomatic recess

PR - Palatine recess

IT - Inferior turbinate

MT - Middle turbinate

IM - Inferior Meatus

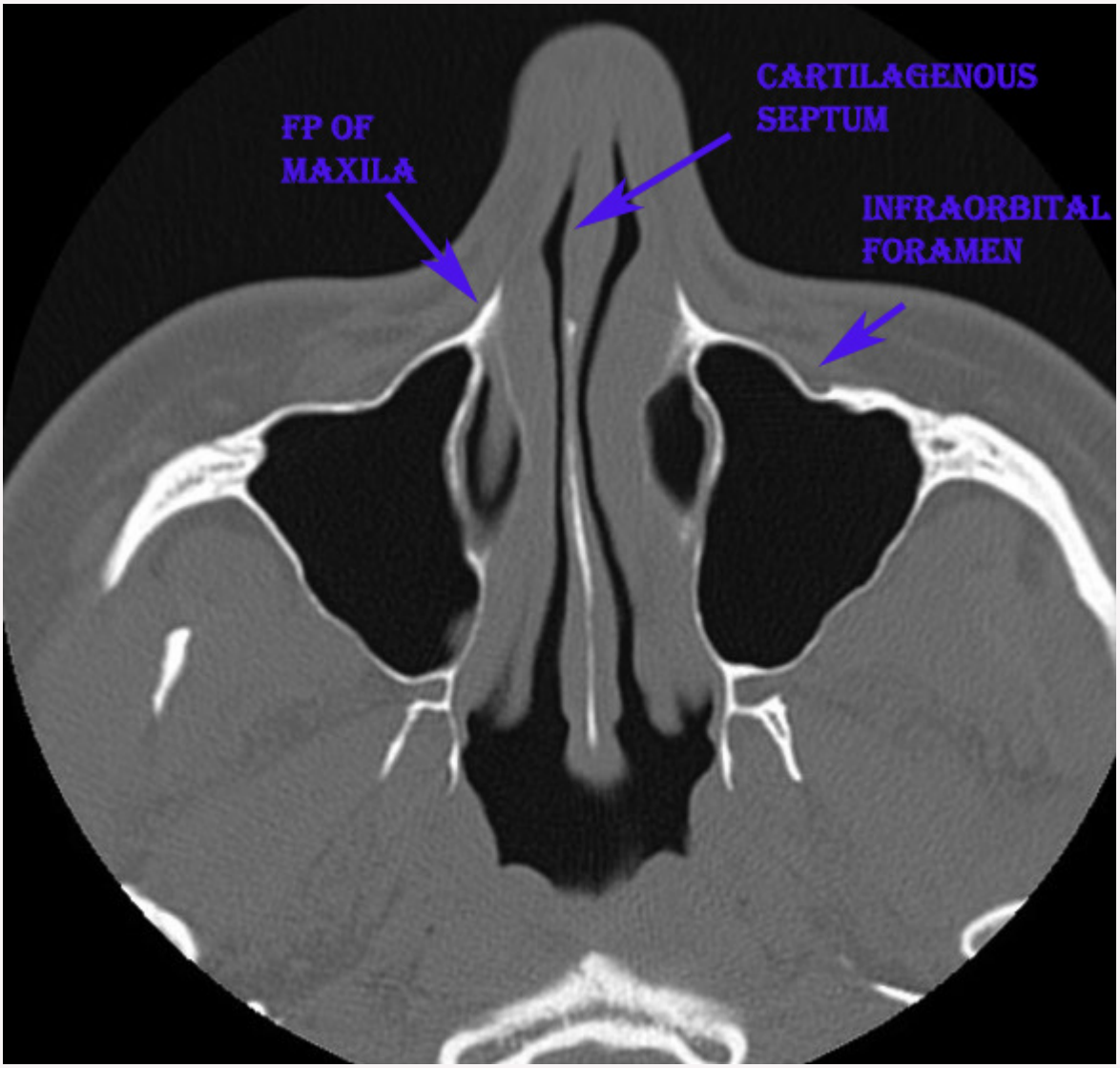


Image showing axial section of nose and sinsues showing the various anatomical structures as labelled in this section.

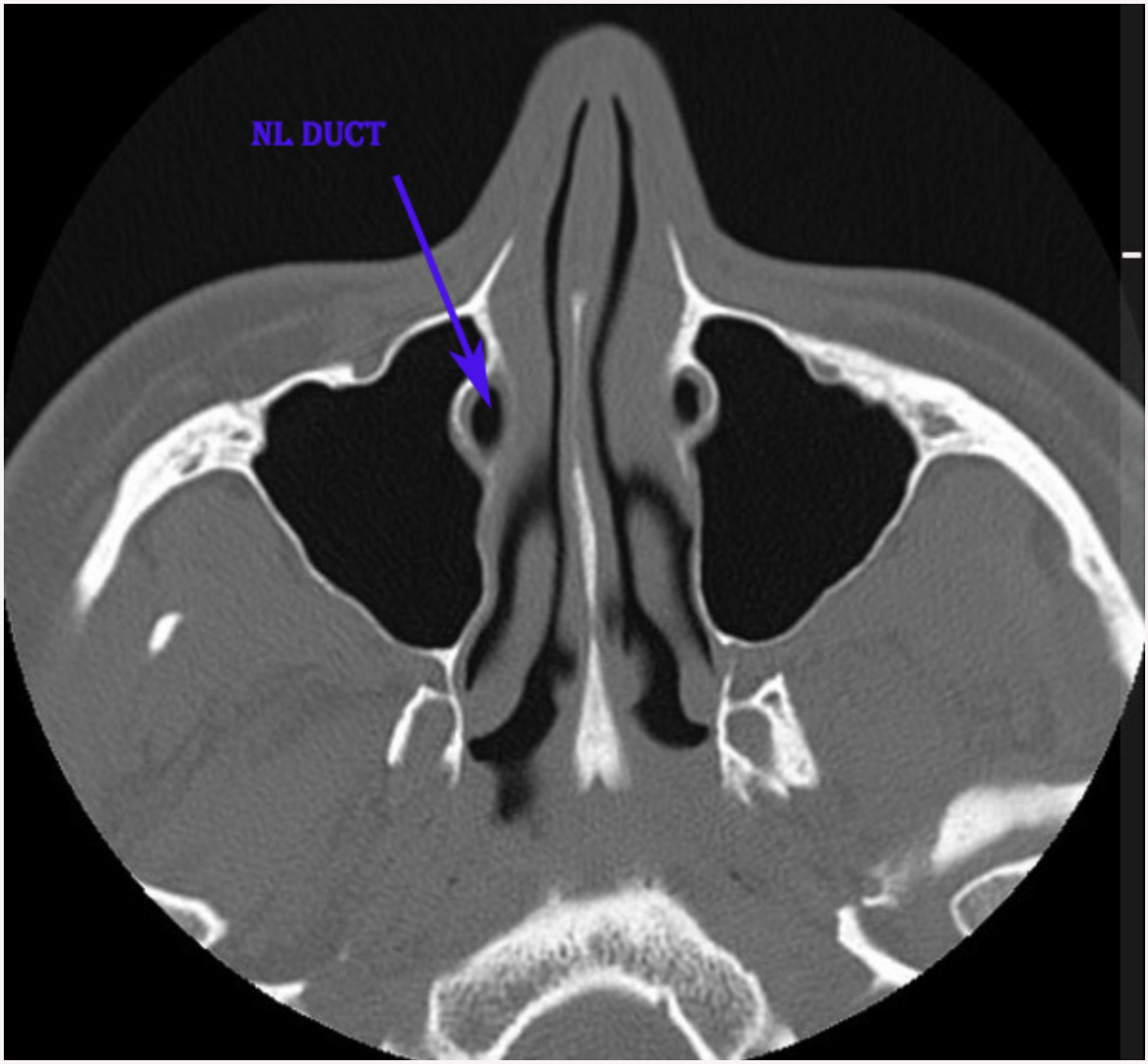


Image showing axial CT of nose and sinuses showing nasolacrimal duct (blue arrow) in this cut. It traverses the medial wall of the maxilla to open inferiorly into the inferior meatus

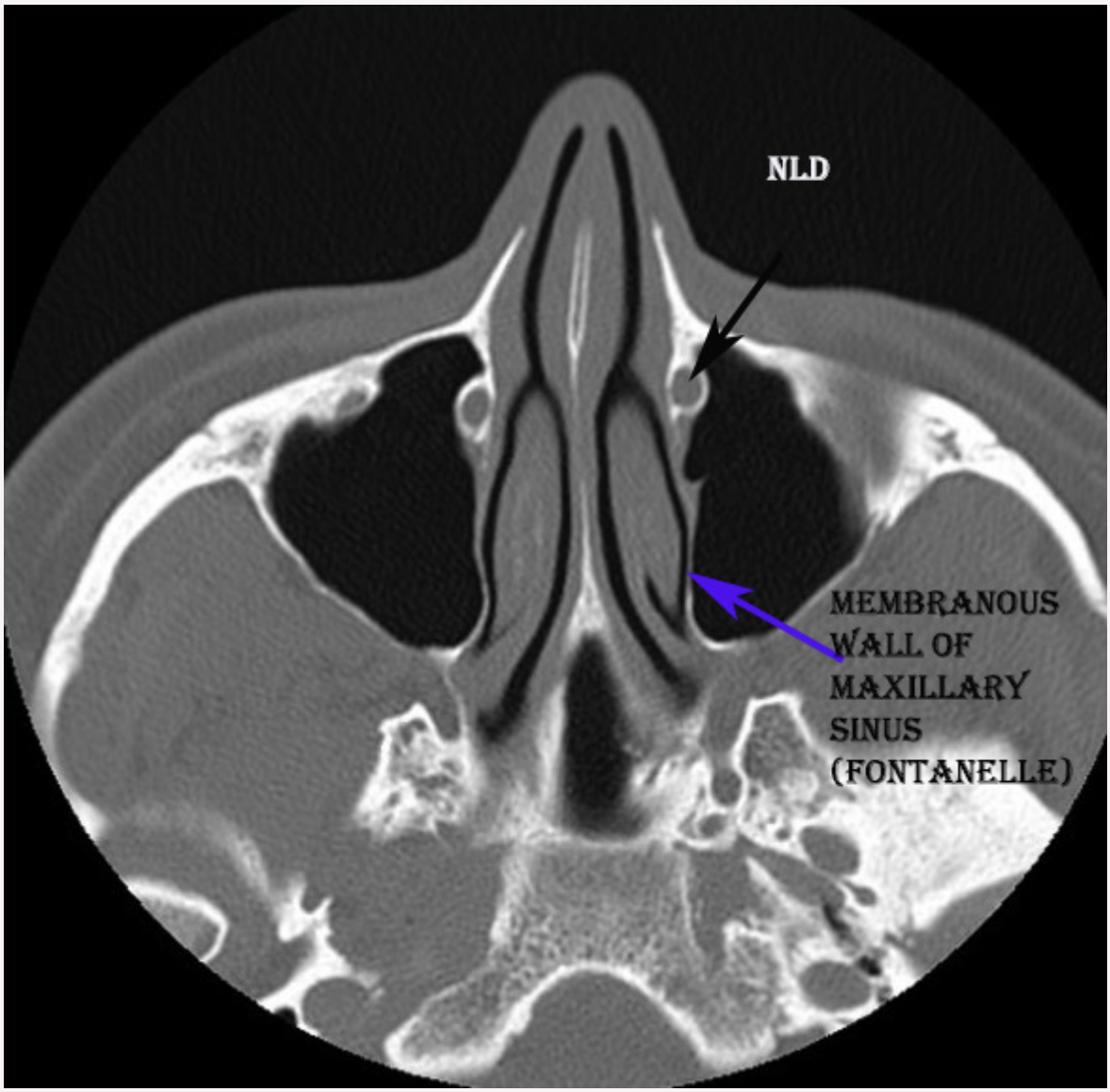


Image showing axial cut of nose and sinuses showing the membranous wall of maxillary sinus (Fontanelle).

NLD - Nasolacrimal duct

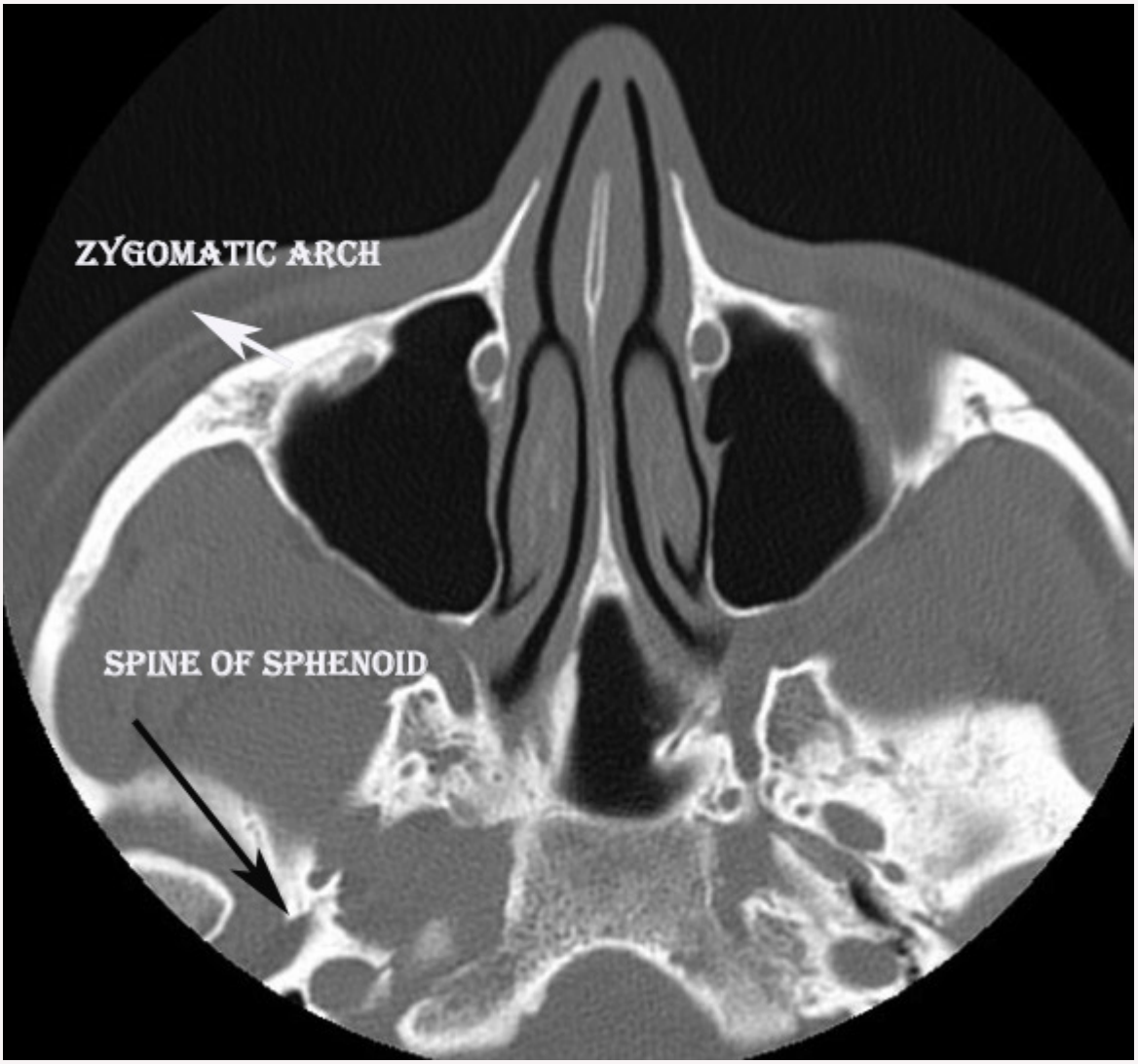


Image showing axial CT of nose and sinuses showing zygomatic arch and spine of sphenoid

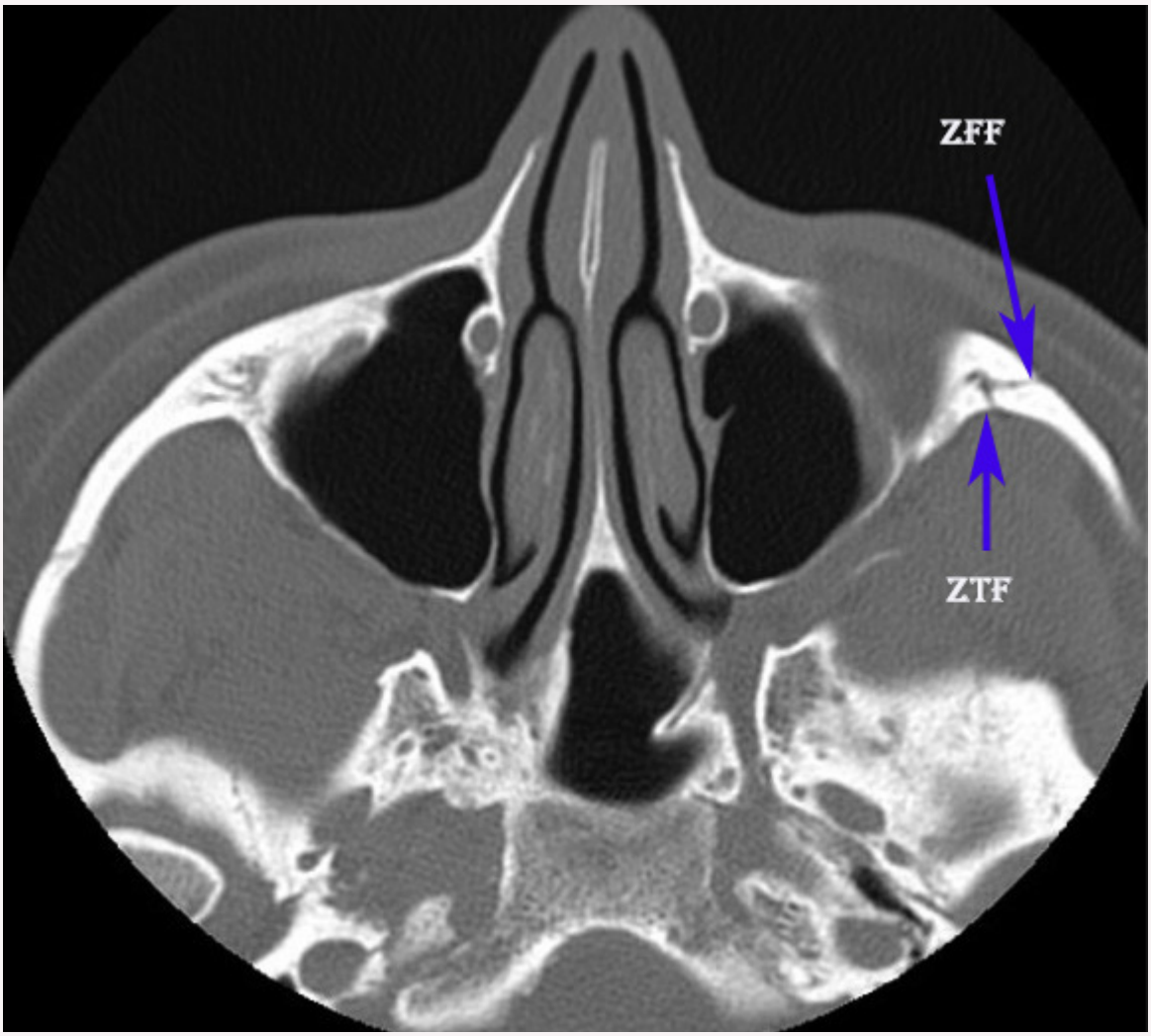


Image showing axial CT of nose and sinuses showing:

ZFF - Zygomatic facial foramen

ZTF - Zygomatico temporal foramen

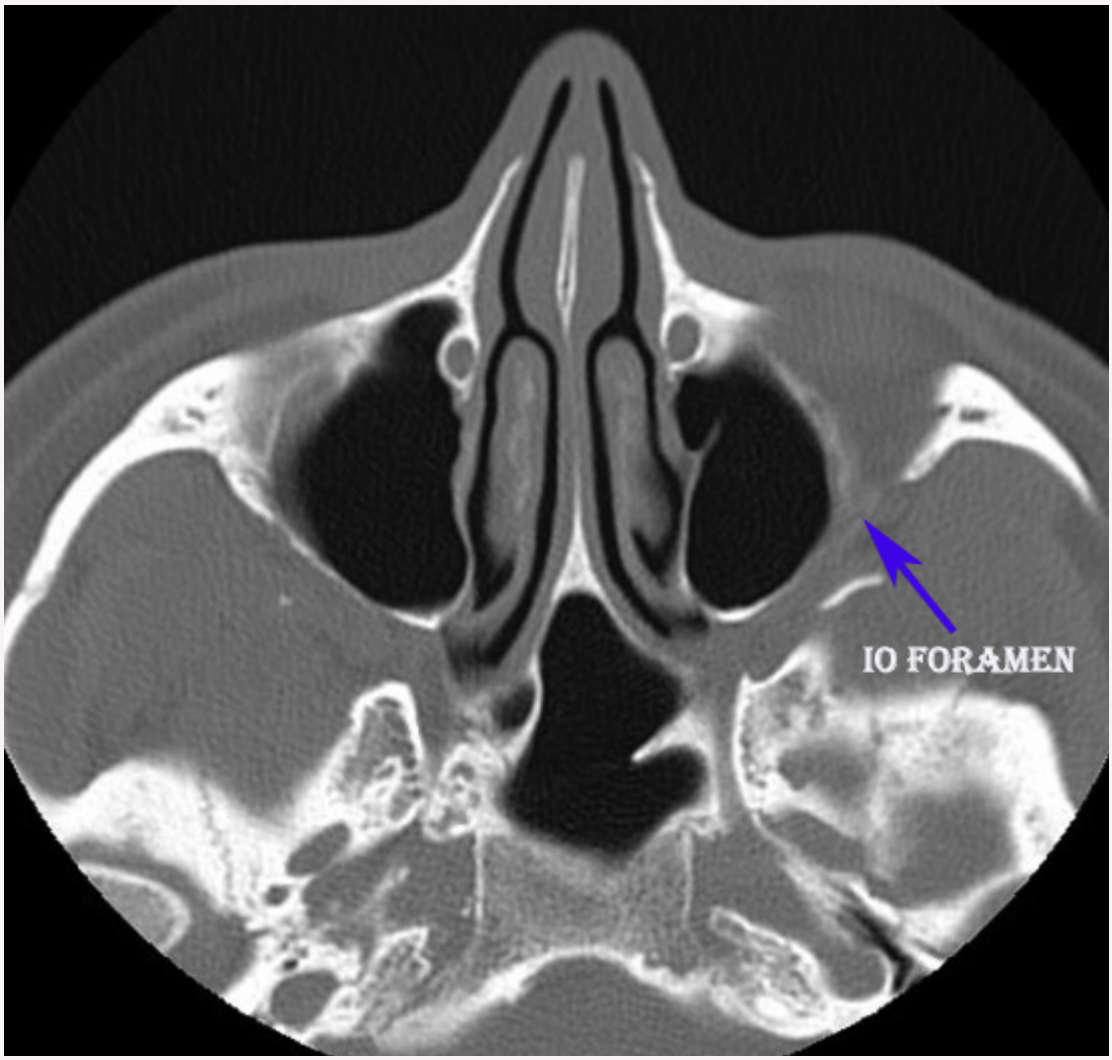


Image showing axial CT nose and sinuses. In this cut note the location of infraorbital foramen (IO foramen)

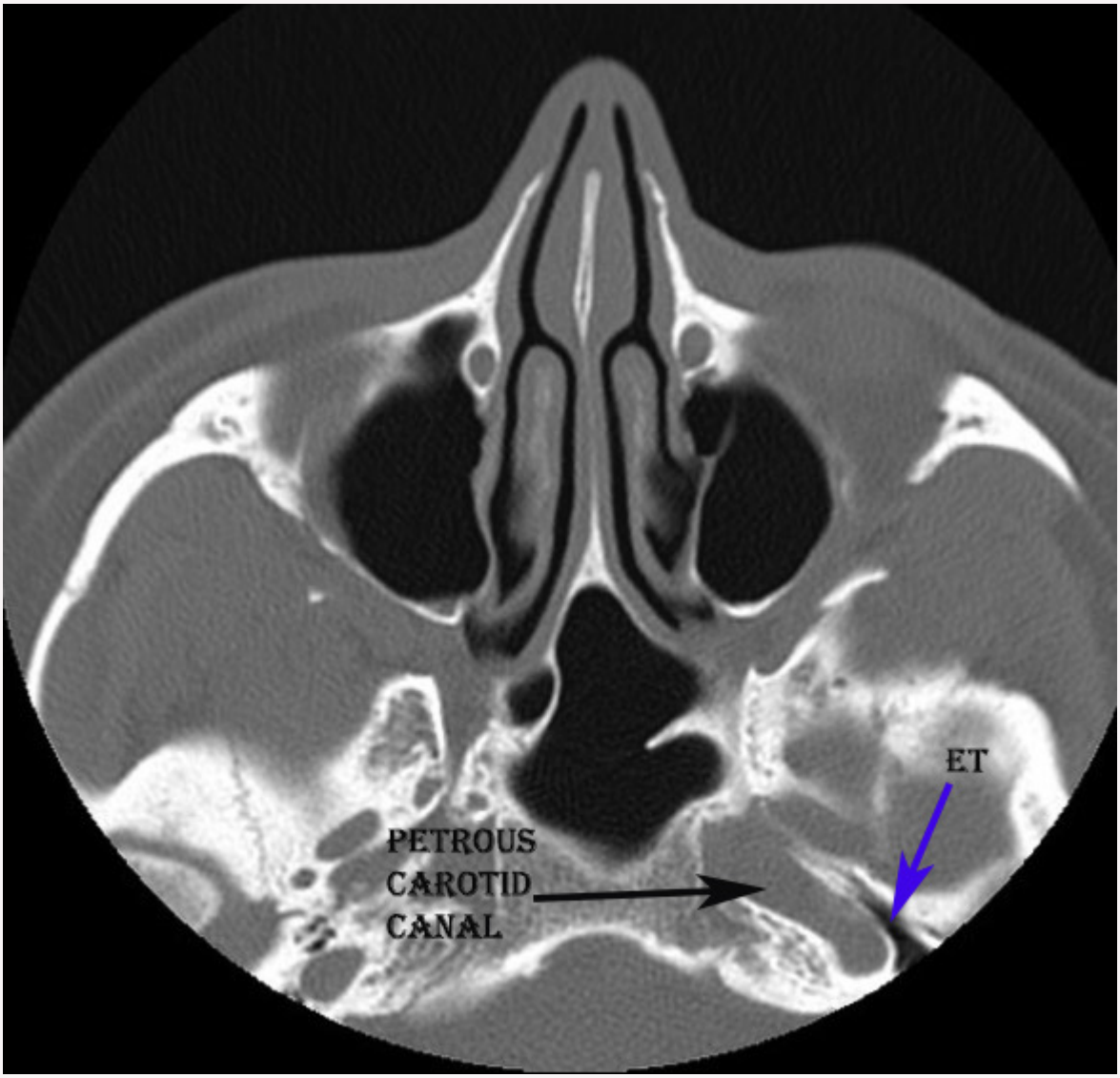
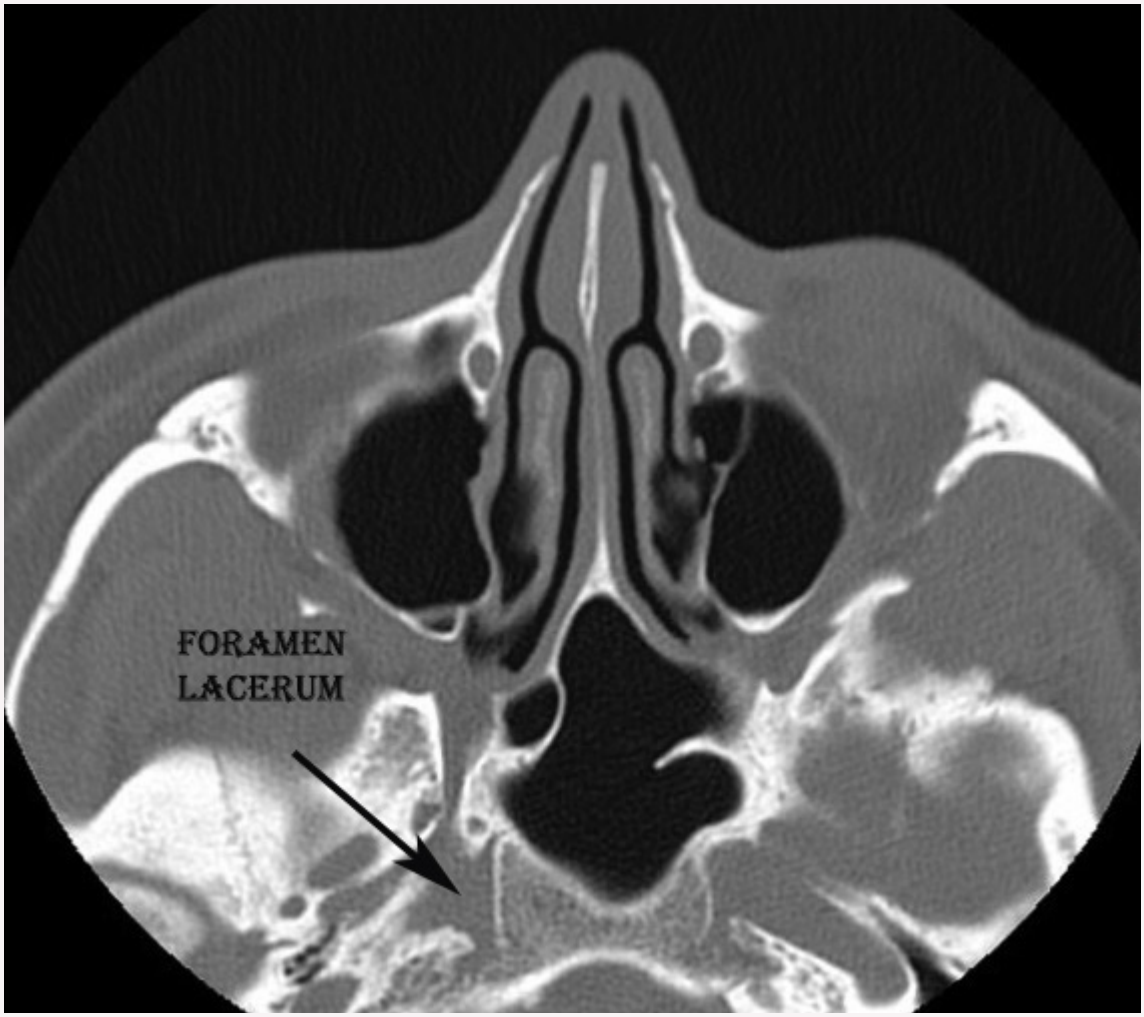


Image showing axial CT of nose and sinuses showing:

ET - eustachean tube

Petrouos carotid canal where horizontal portion of internal carotid artery traverses



Iamge showing axial CT of nose and sinuses. In this cut foramen lacerum is clearly seen. (Black arrow)

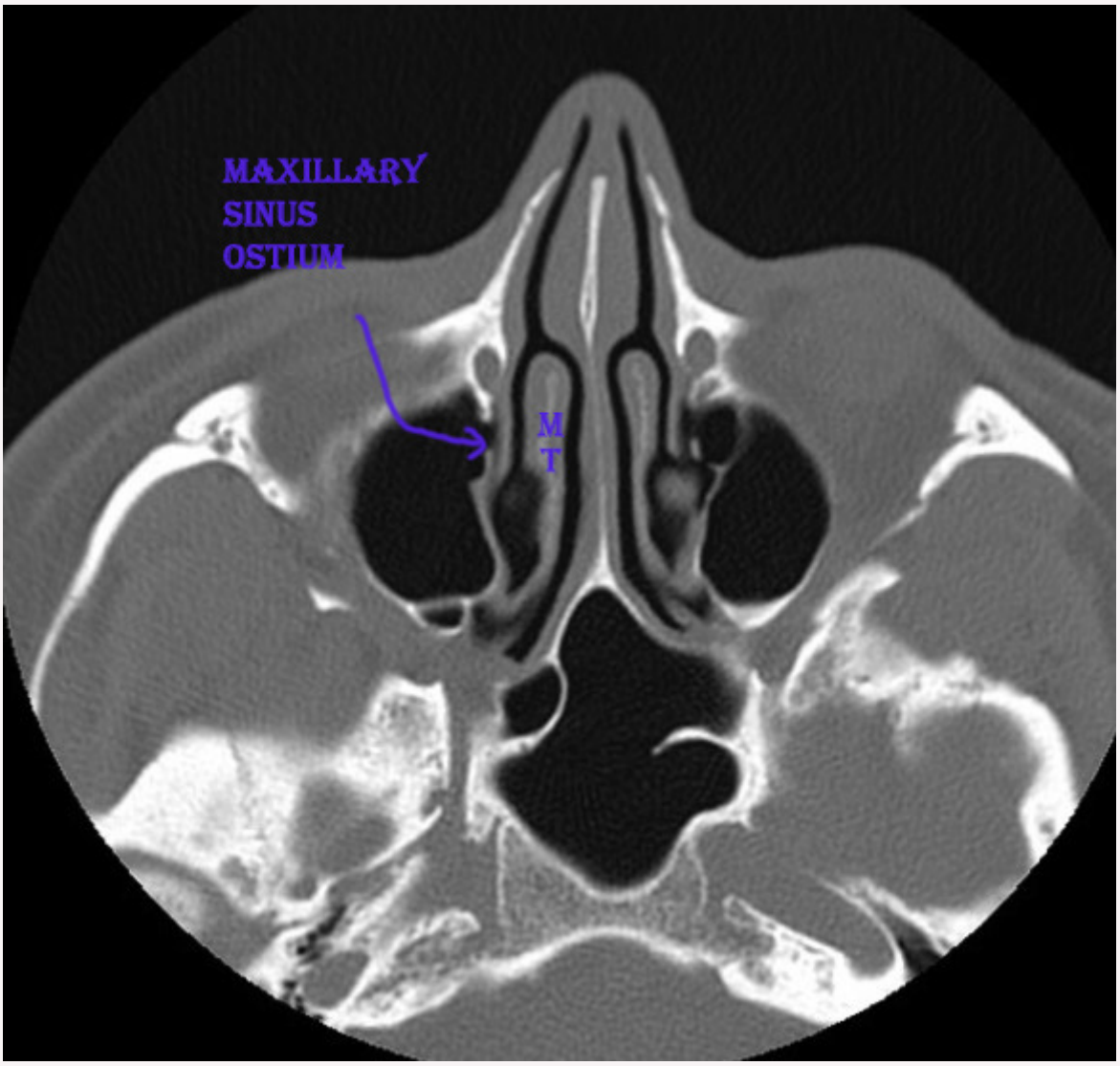


Image showing axial CT of nose and sinuses demonstrating the location of maxillary sinus ostium. The middle turbinate is also seen in this cut (MT)

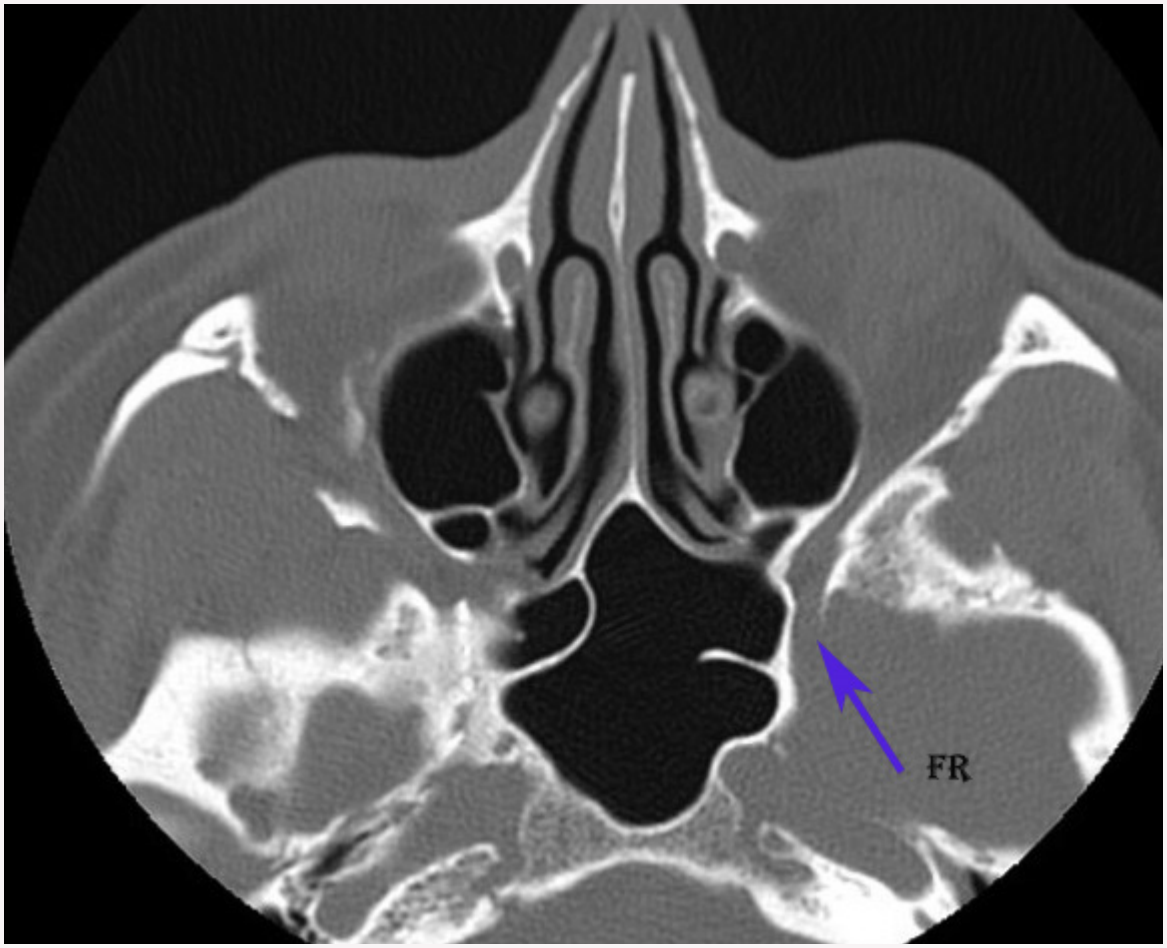


Image showing axial CT of nose and sinuses showing Foramen Rotundum (FR)

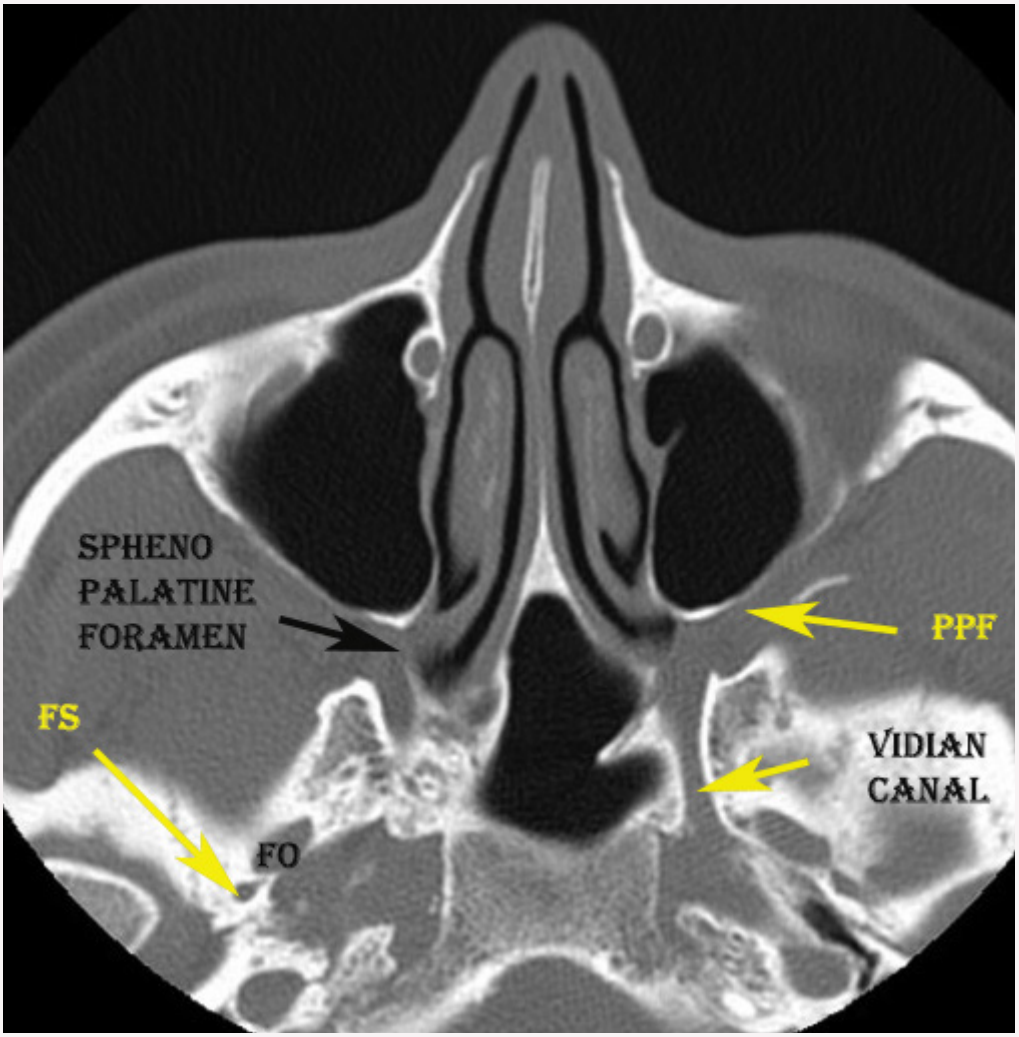


Image showing axial CT nose and sinuses showing:

Vidian canal

PPF - Pterygopalatine fossa

Sphenopalatine foramen

FO - Foramen ovale

FS - Foramen spinosum

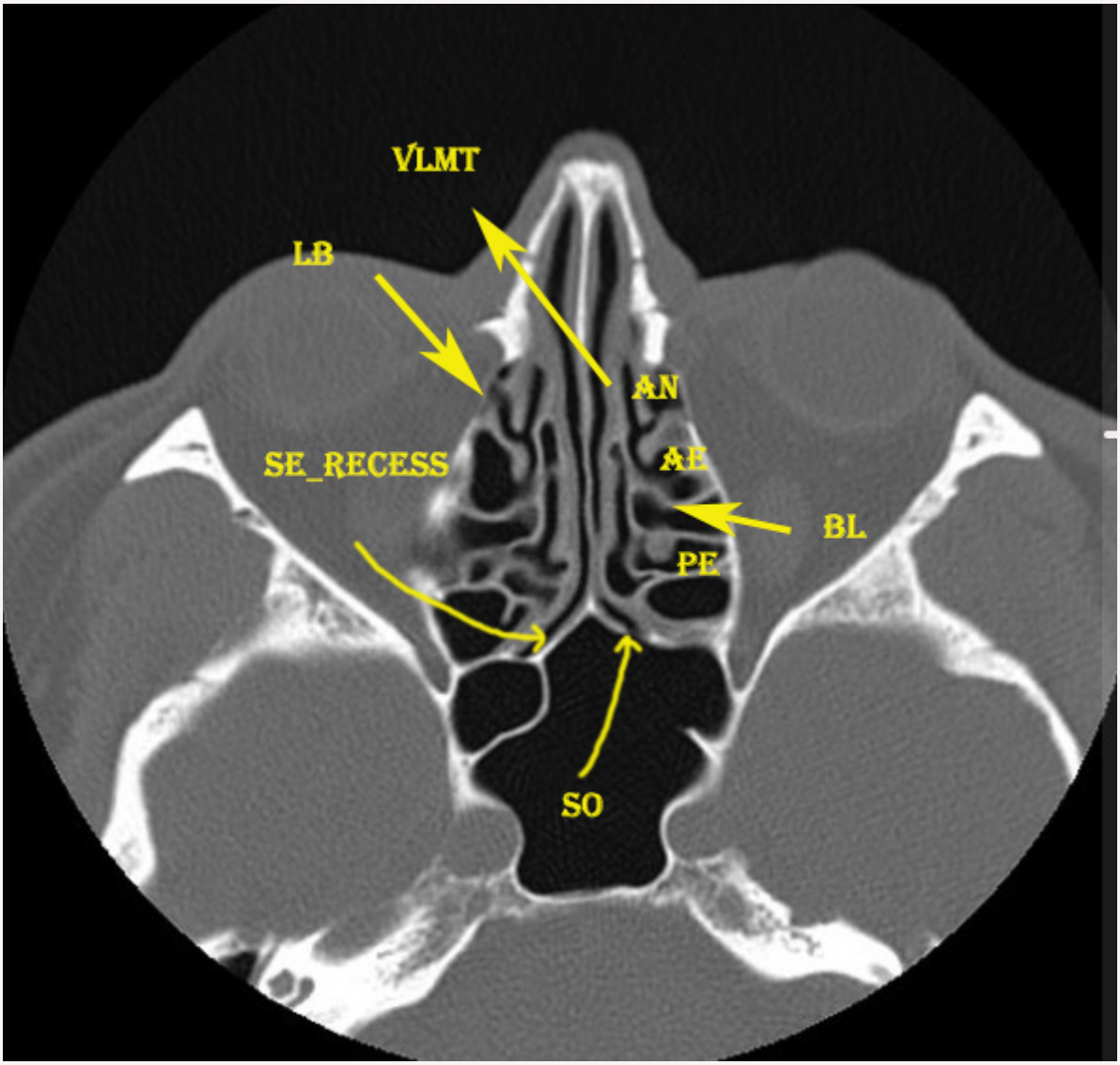


Image showing Axial CT of nose and sinuses. Following structures are seen:

VLMT - Vertical lamella of middle turbinate

AN - Agger nasi cell

AE - Anterior ethmoid air cell

BL - Basal lamella

PE - Posterior ethmoid air cells

SO - Sphenoid ostium

SE_Recess - Sphenoethmoidal recess

LB - lacrimal bone

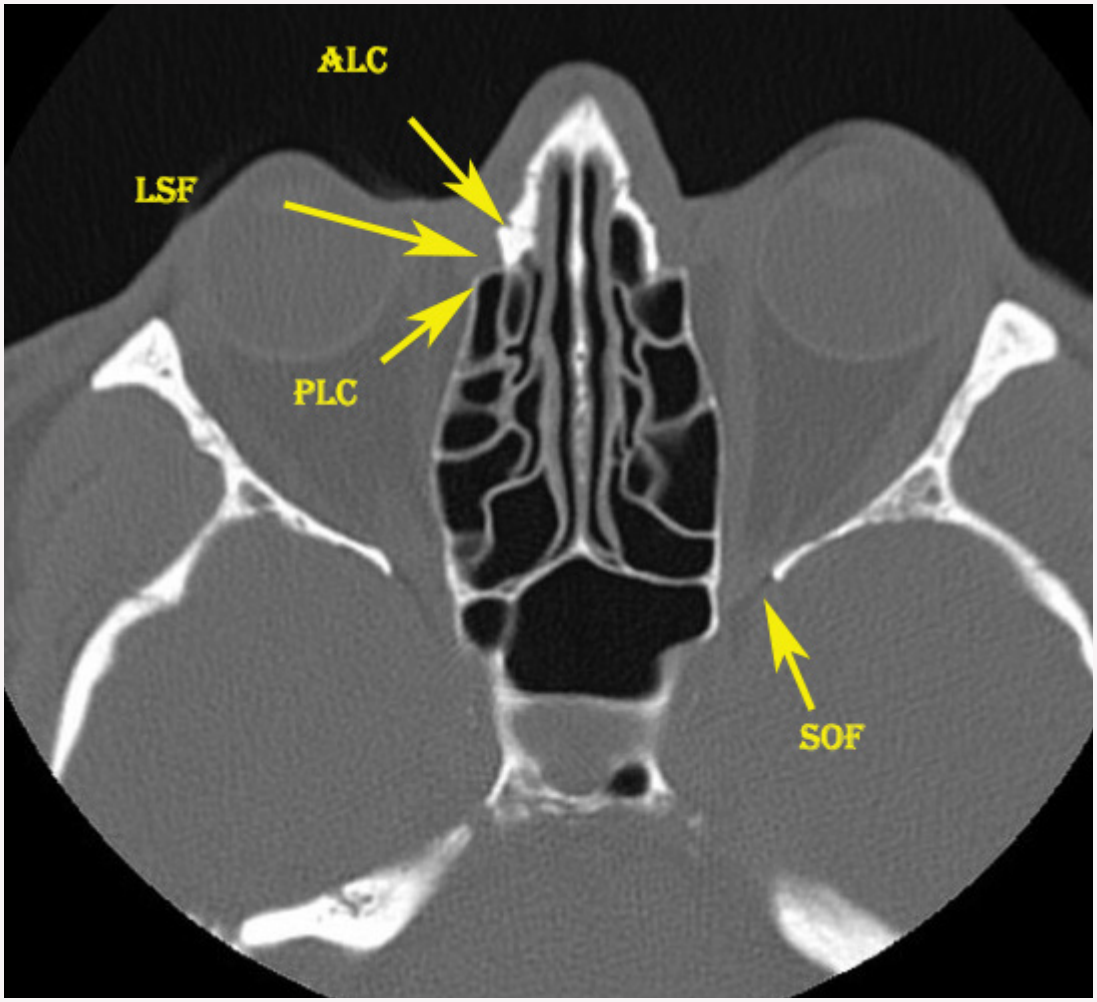


Image showing axial CT of nose and sinuses showing:

ALC - Anterior lacrimal crest

LSF - Lacrimal sac fossa

PLC- Posterior lacrimal crest

SOF - Superior orbital fissure

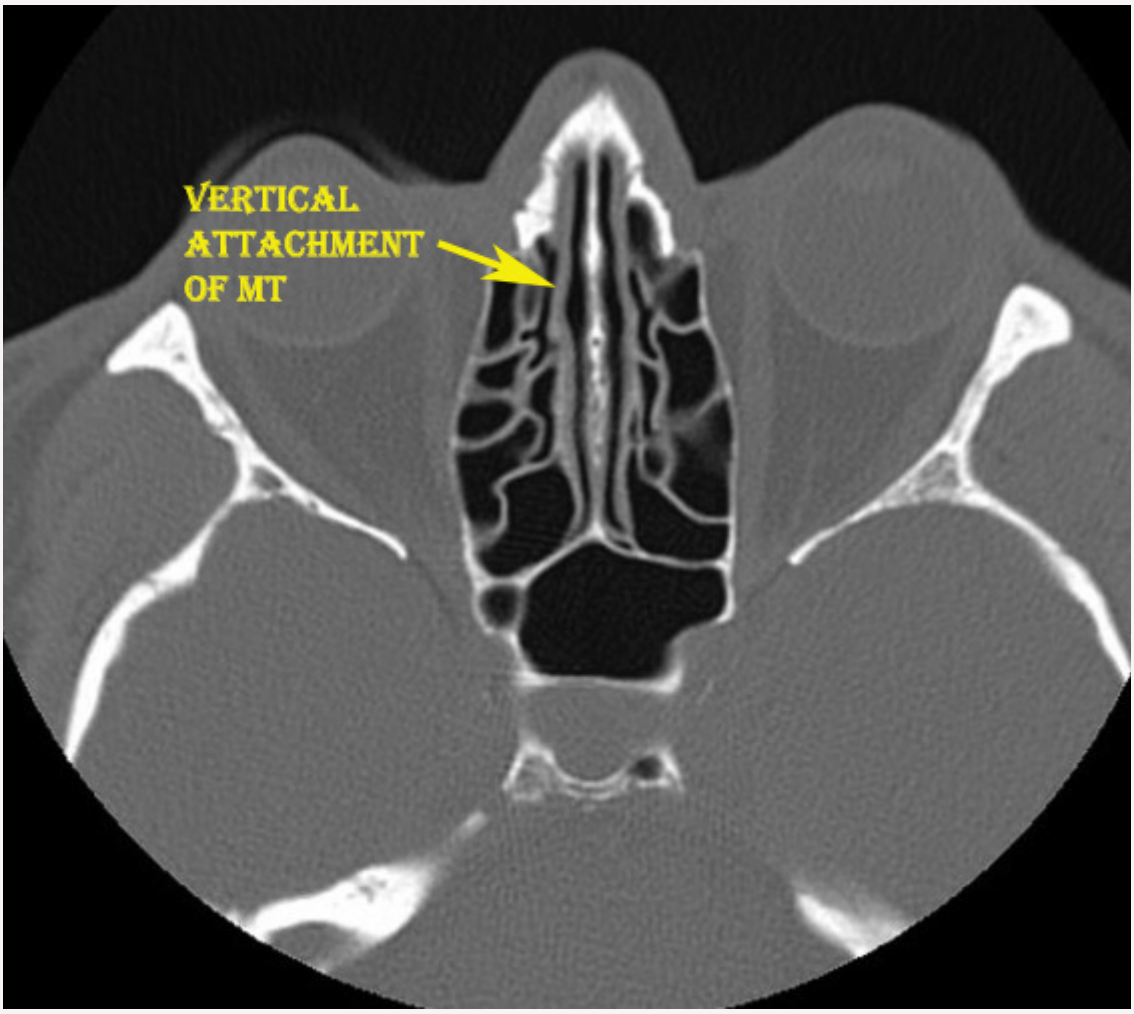


Image showing axial CT of nose and sinuses showing vertical attachment of middle turbinate

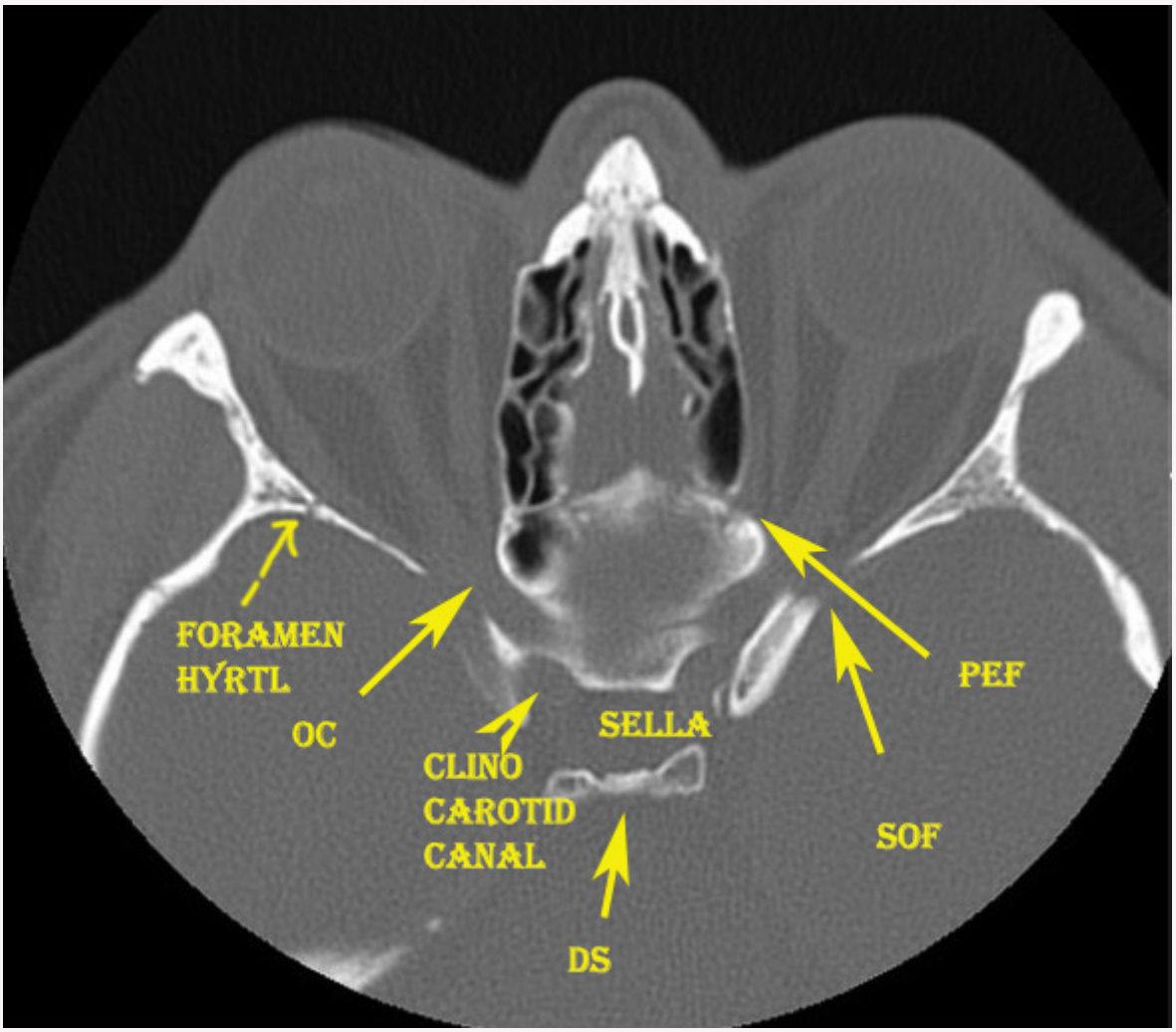


Image showing axial CT of nose and sinuses. Structures seen in this cut include:

PEF - Posterior ethmoidall foramen

SOF - Superior orbital fissure

DS - Dorsum sella

OC - Optic canal

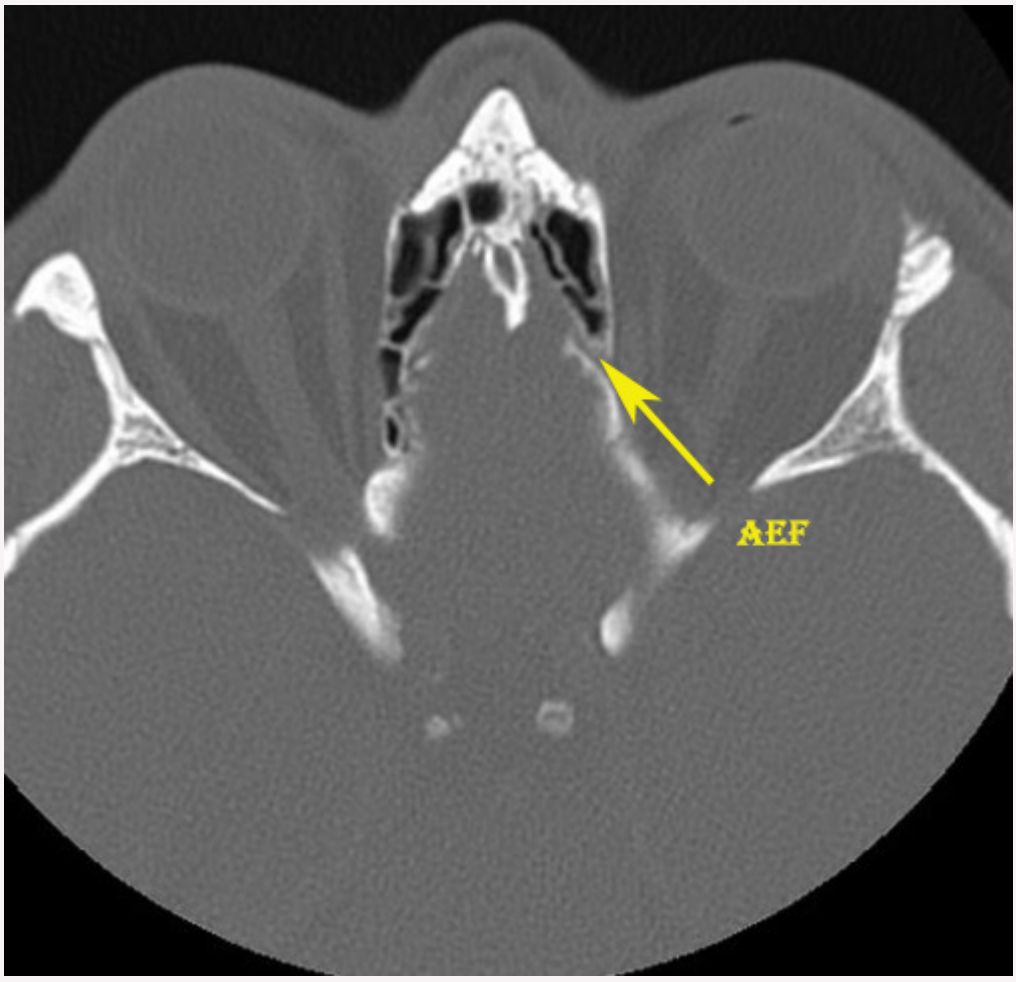


Image showing axial CT of nose and sinuses showing:

AEF - Anterior ethmoidal foramen

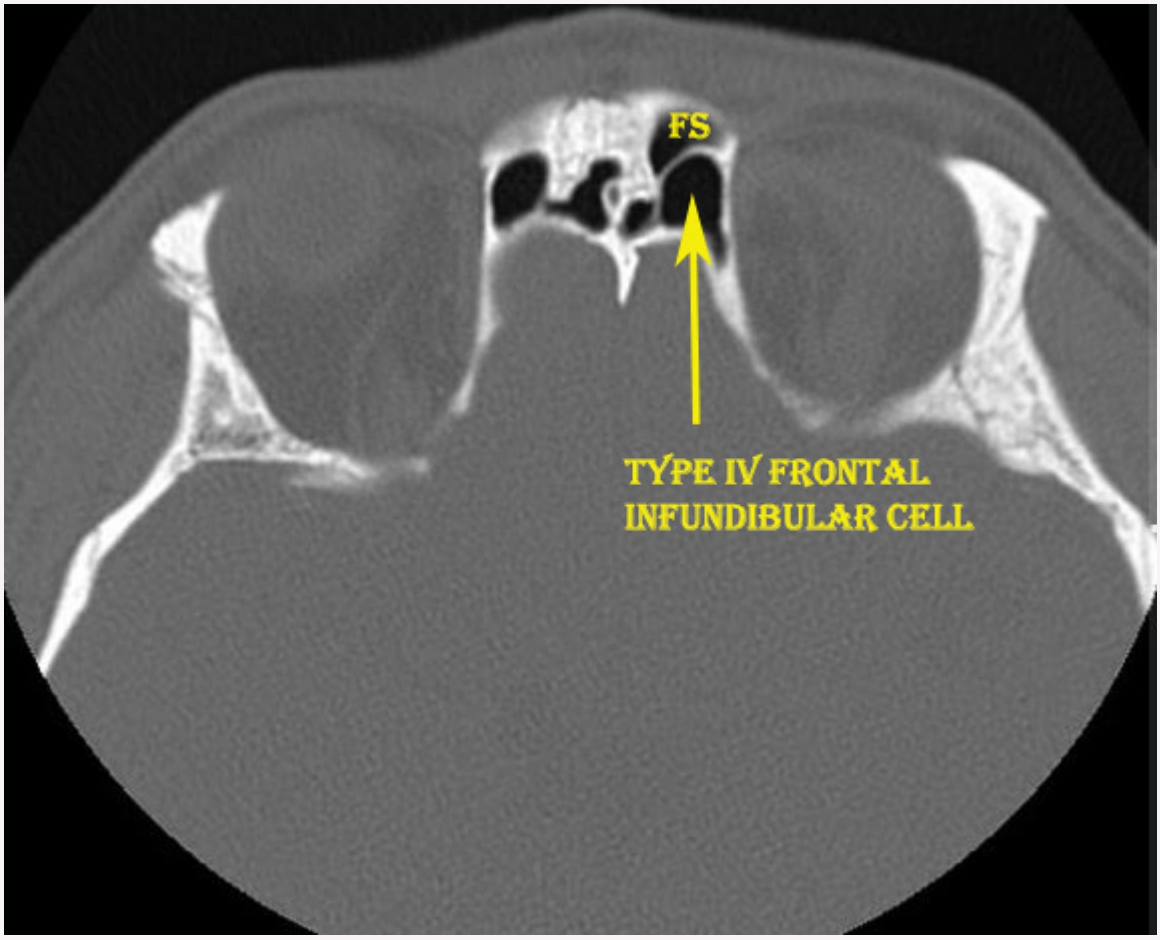


Image showing axial CT section of nose and sinuses taken at the level of frontal sinus. It showes the interior of frontal sinus and along with it the Type IV frontal cell.

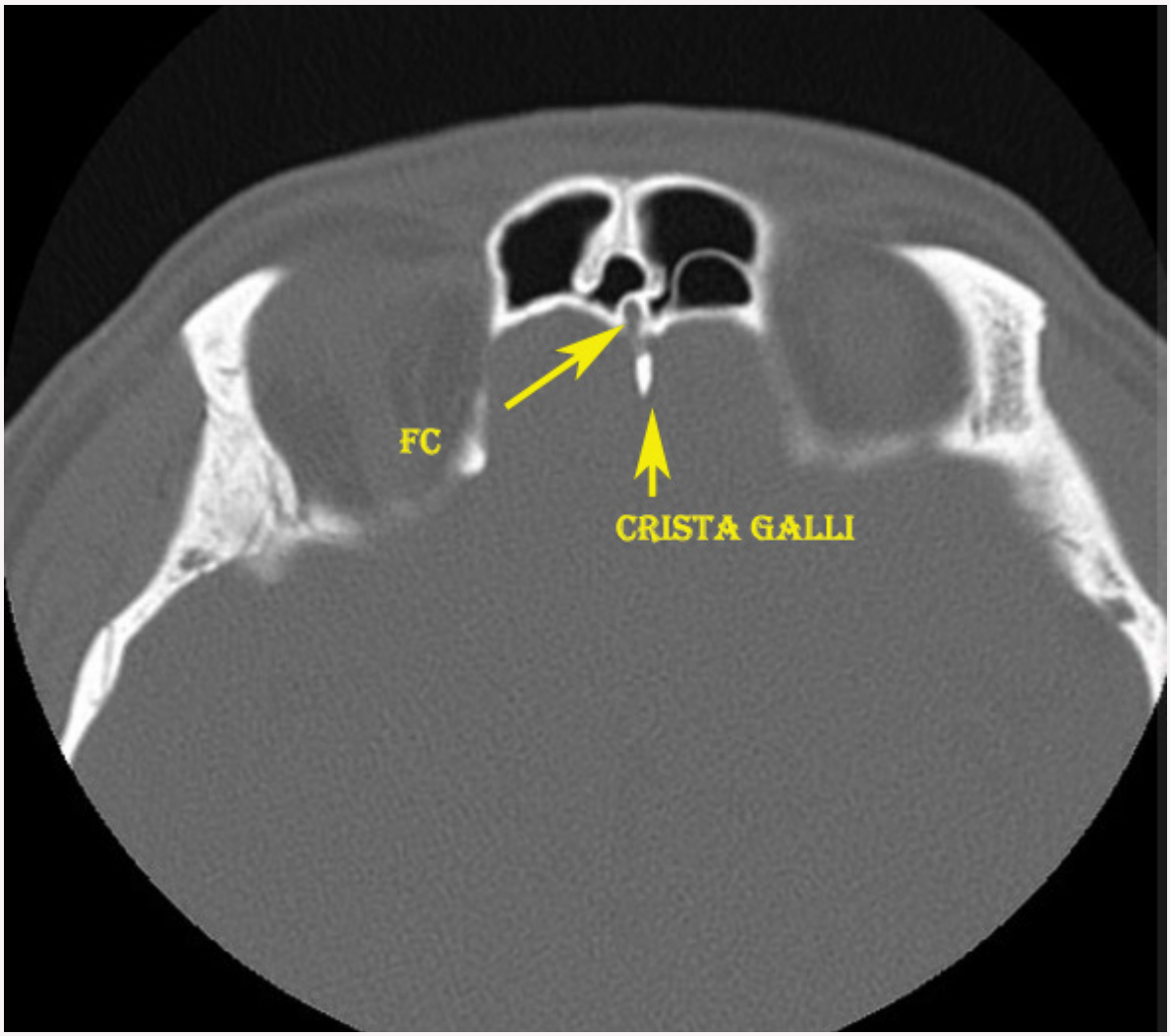


Image showing axial cut of nose and sinuses showing:

FC - Foramen caecum

Crista galli

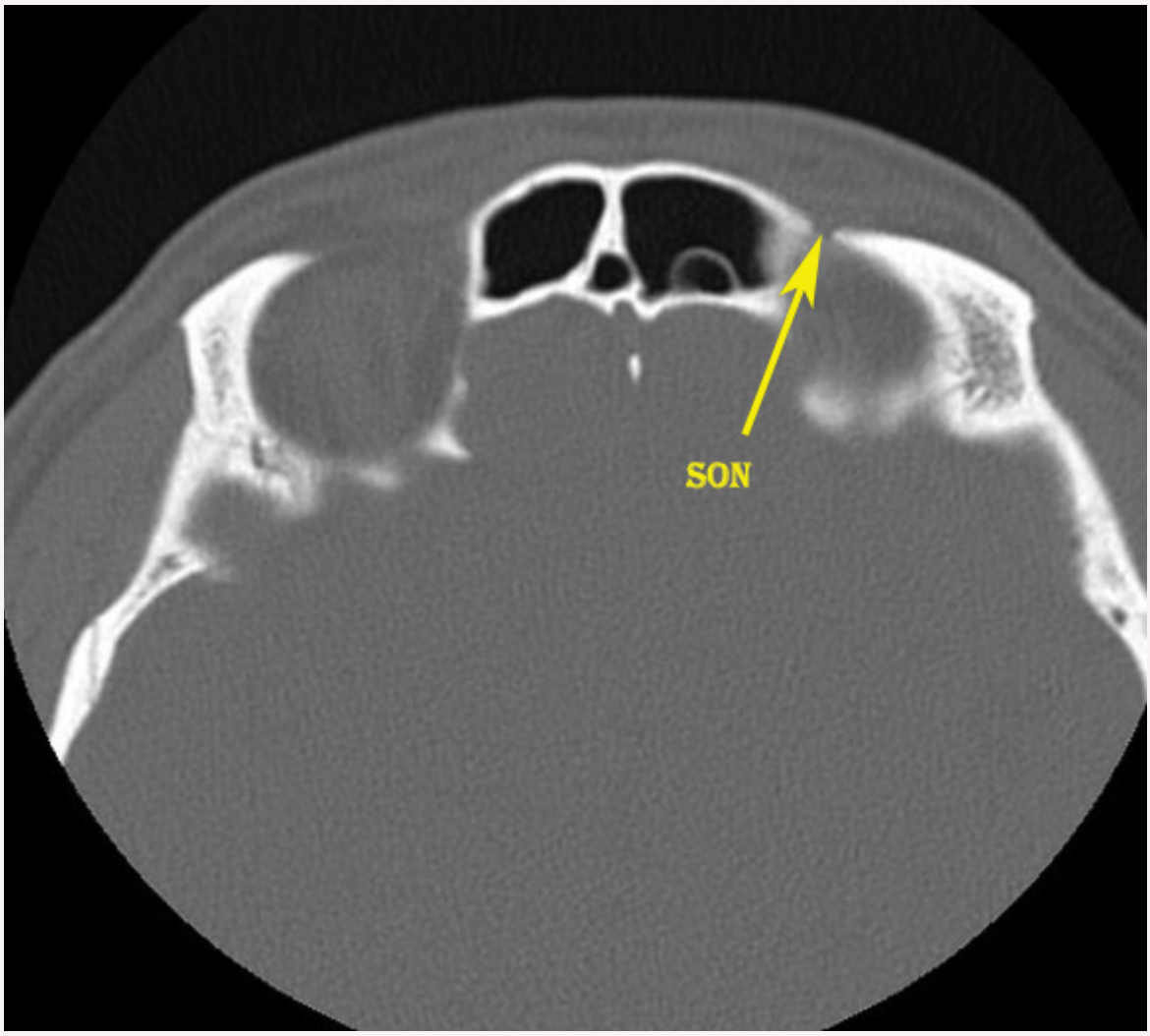


Image showing axial cut of nose and sinuses showing:

SON - Supraorbital notch

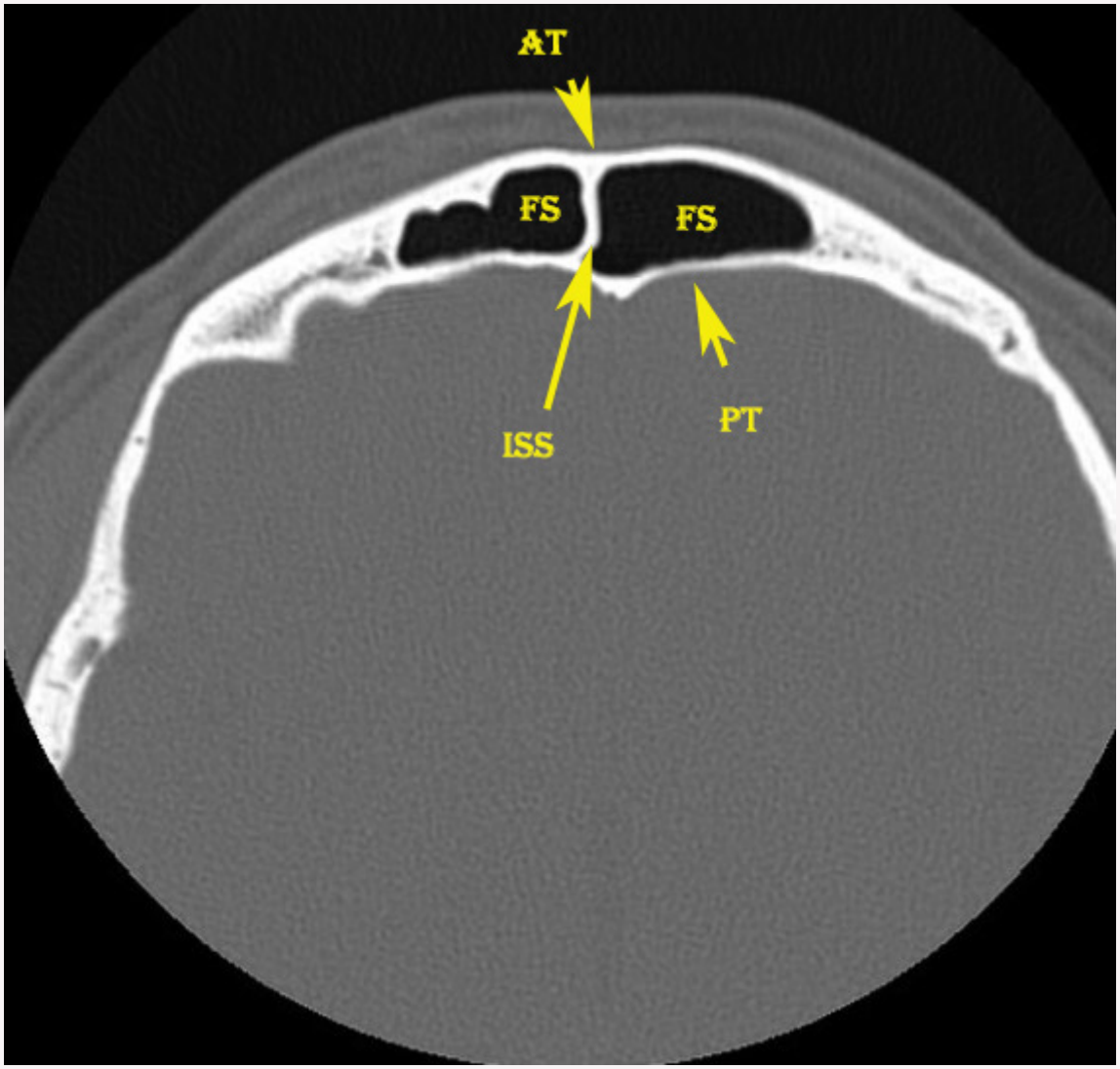


Image showing axial CT nose and sinuses taken at the level of frontal sinus.

FS - Frontal sinus

AT - Anterior table

PT - Posterior table

ISS - Intersinus septum

Axial cuts shows both anterior and posterior tables of frontal sinus. Involvement of posterior table of frontal sinus by disease process can be made out clearly in axial scans.

Simultaneous comparison of coronal and axial scans of nose and sinuses:

Otolaryngologists should be familiar with anatomy of nose and sinuses as revealed by axial and coronal sections. Study of coronal sections is mandatory before proceeding with endoscopic sinus surgery. Thin sections taken in coronal plane will reveal cell by cell anatomy of the entire ethmoidal air cell system. Ideally 1 mm cuts is preferred. Coronal sections provide the surgeon the anatomical view of the area as they would encounter during the surgery. It would not be out of place to embark on comparative study of anatomy revealed by coronal and axial cuts. In previous chapters both cornal and axial sectional anatomy was dealt with individually. In this section there will a cut by cut comparison between axial and coronal CT sections.

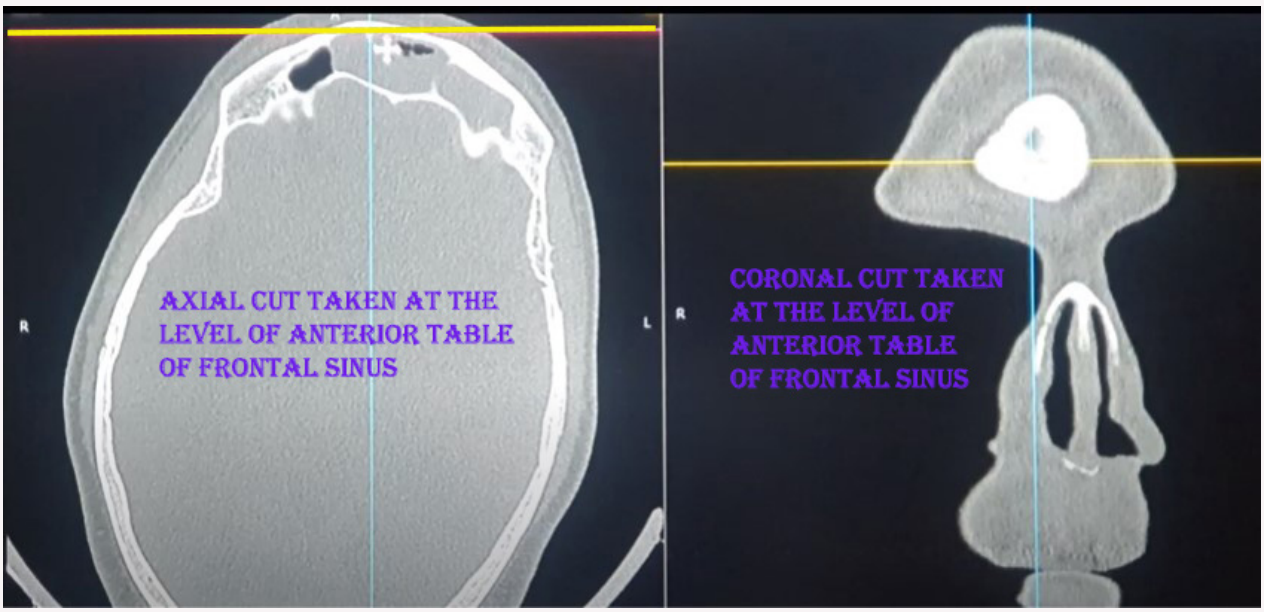

AXIAL CUT TAKEN AT THE LEVEL OF ANTERIOR TABLE OF FRONTAL SINUS
R
L
CORONAL CUT TAKEN AT THE LEVEL OF ANTERIOR TABLE OF FRONTAL SINUS
R

Image showing axial and coronal cuts of nose and sinuses taken at the same level (frontal sinus). Note axial view shows both tables of frontal sinus while coronal views show only the anterior table in this section. Nasal cavities and nasal septum are visible in coronal cut. Anterior table of frontal sinus appears as a dense white structure in the coronal section.

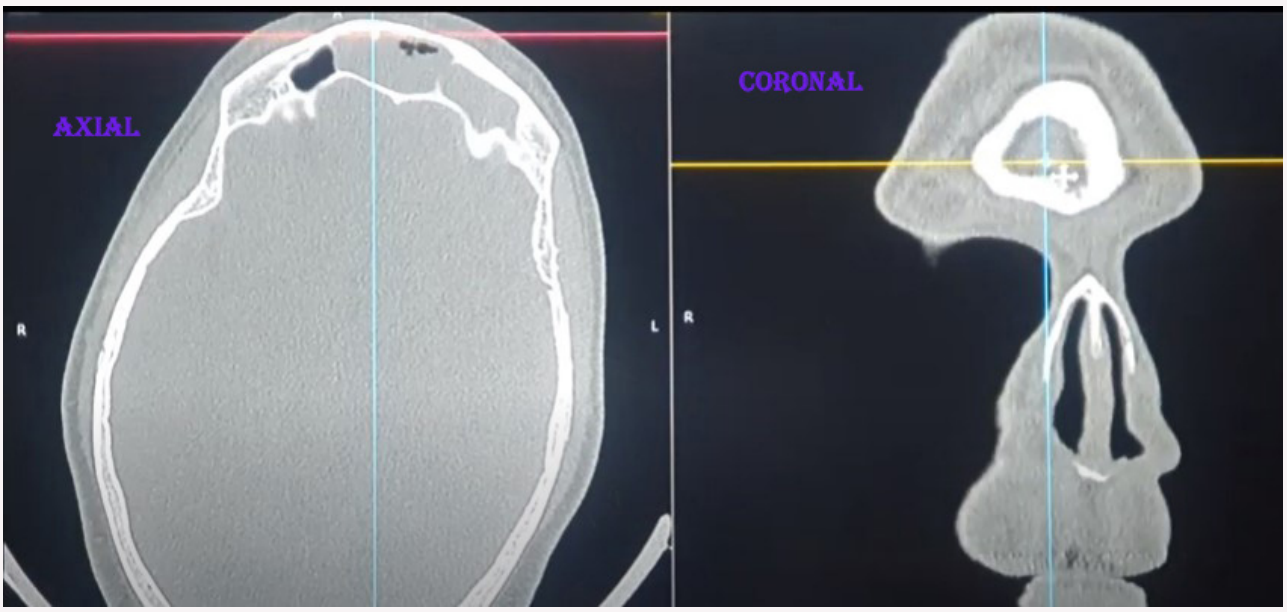


Image showing axial cut of nose and sinuses and the corresponding coronal section. This image shows the entire frontal sinus (both tables) visible in the axial section, while the frontal sinus along with its content (air) could be seen in the coronal section. Posterior wall of frontal sinus is not seen in coronal section in this cut. Nasal pyramid is clearly seen in coronal section in this cut.

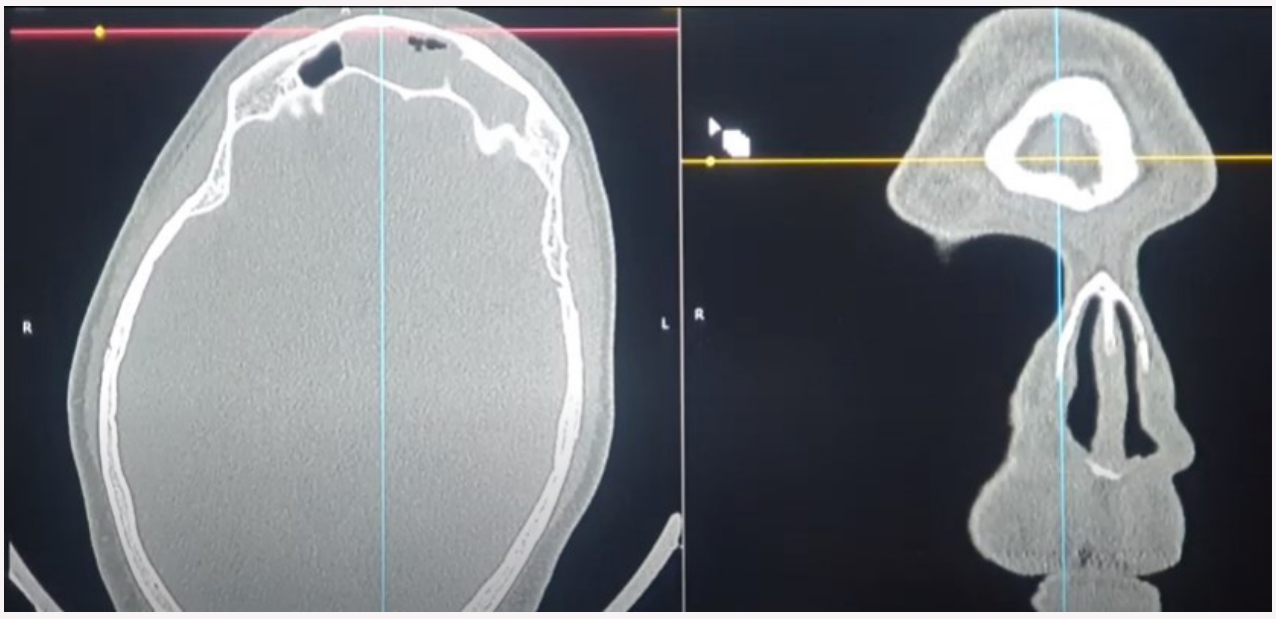


Image showing comparison between axial and coronal CT nose and sinuses taken at the same level. Interfrontal septum is not visible and hence the side of the frontal sinus cannot be commented. In the coronal cut Nasal pyramid and perpendicular plate of ethmoid and cartilagenous nasal septum can be clearly seen

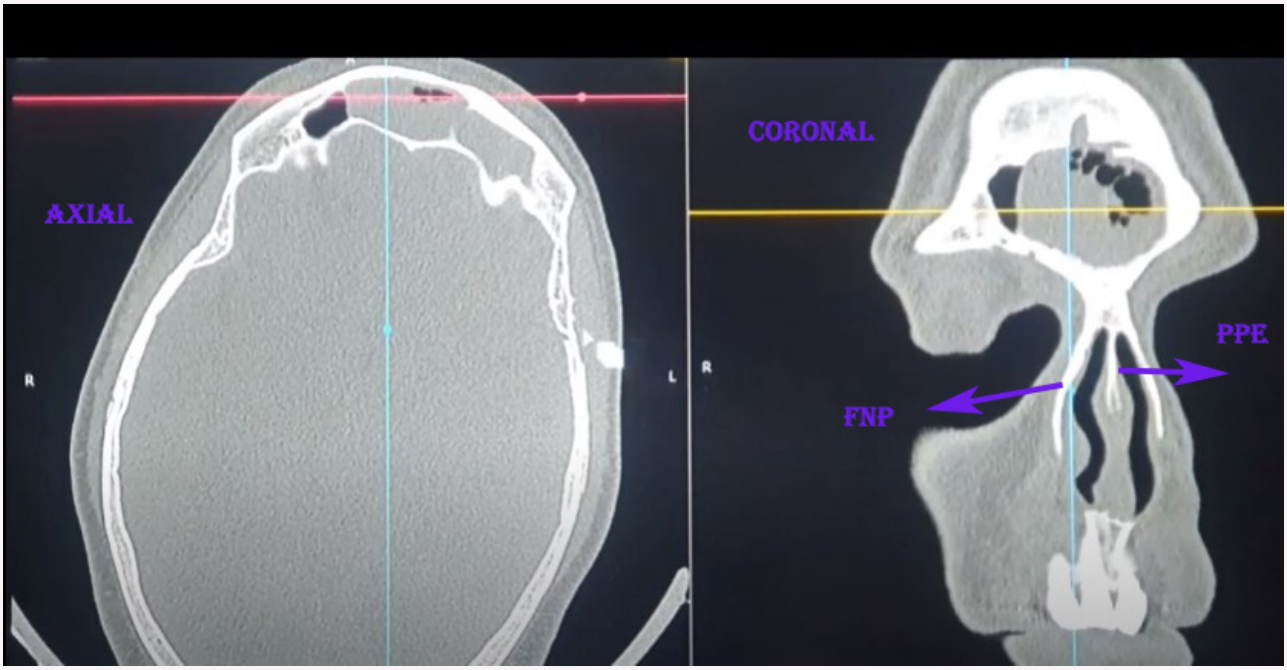


Image showing axial and corresponding coronal section of CT nose and sinuses. In this image frontal sinus along with its anterior and posterior tables are clearly seen in axial cut. In the coronal cut frontal sinus cavity is seen. Posterior wall of the maxillary sinus is not visible. Frontonasal process of maxilla and nasal bone forming the nasal bony pyramid is seen in the coronal CT. Perpendicular plate of ethmoid and cartilagenous portion of nasal septum are also seen in coronal CT cut. Posterior table of frontal sinus is not visible in coronal cuts.

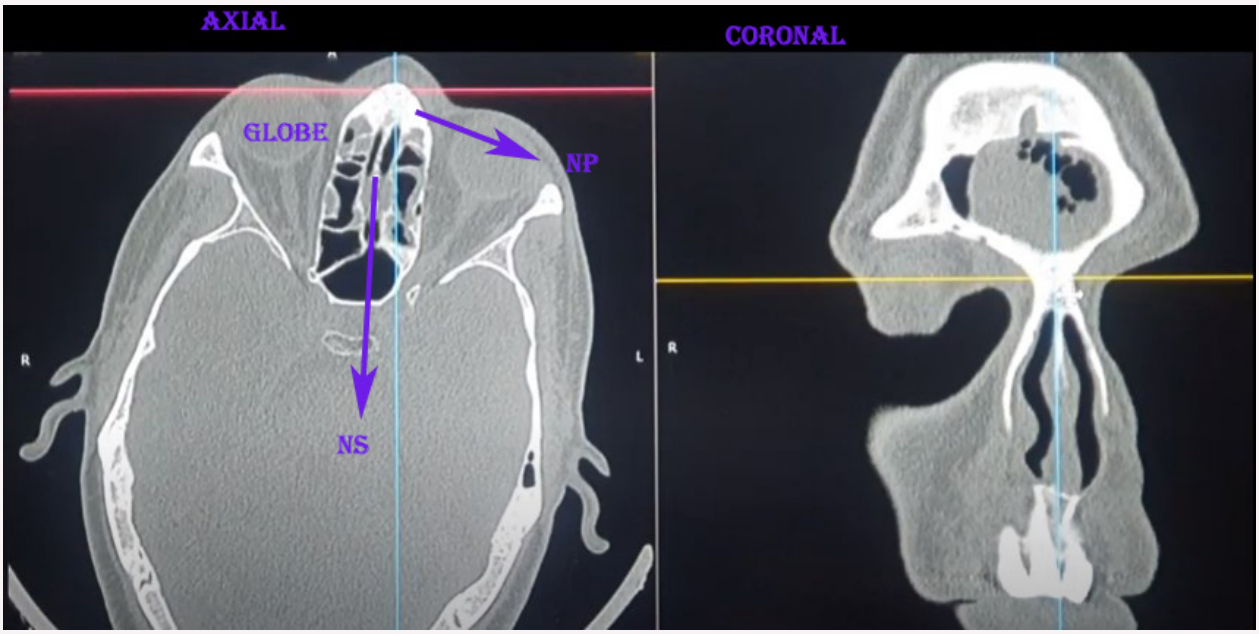


Image showing axial and coronal section of nose and sinuses taken at the level of nasal beak.
NP - Nasal pyramid
NS - Nasal septum

In axial cut taken at this level the nasal septum is fully visible in its antero-posterior direction. Pinna is also visible. In the coronal section the nasal septum is visible vertically in a supero inferior direction.

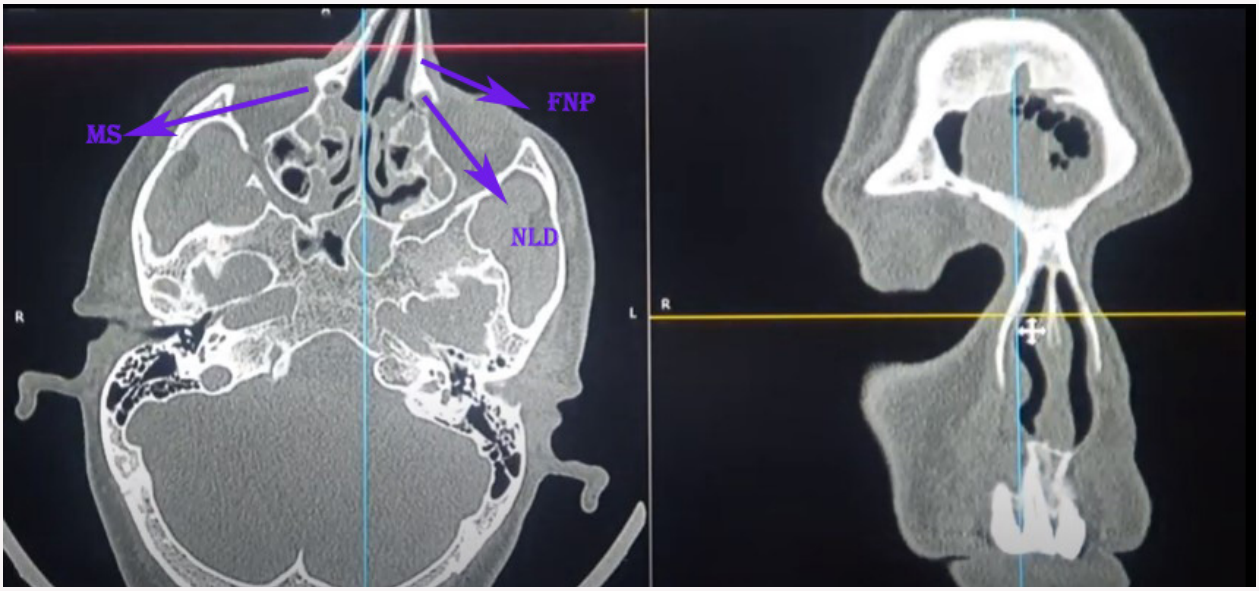


Image showing axial and coronal cuts of nose and sinuses. Pink horizontal line in the axial section indicates the level of coronal cut.

NLD - Nasolacrimal duct

MS - Origins of maxillary sinus

FNP - Frontonasal process of maxilla (longer & thicker)

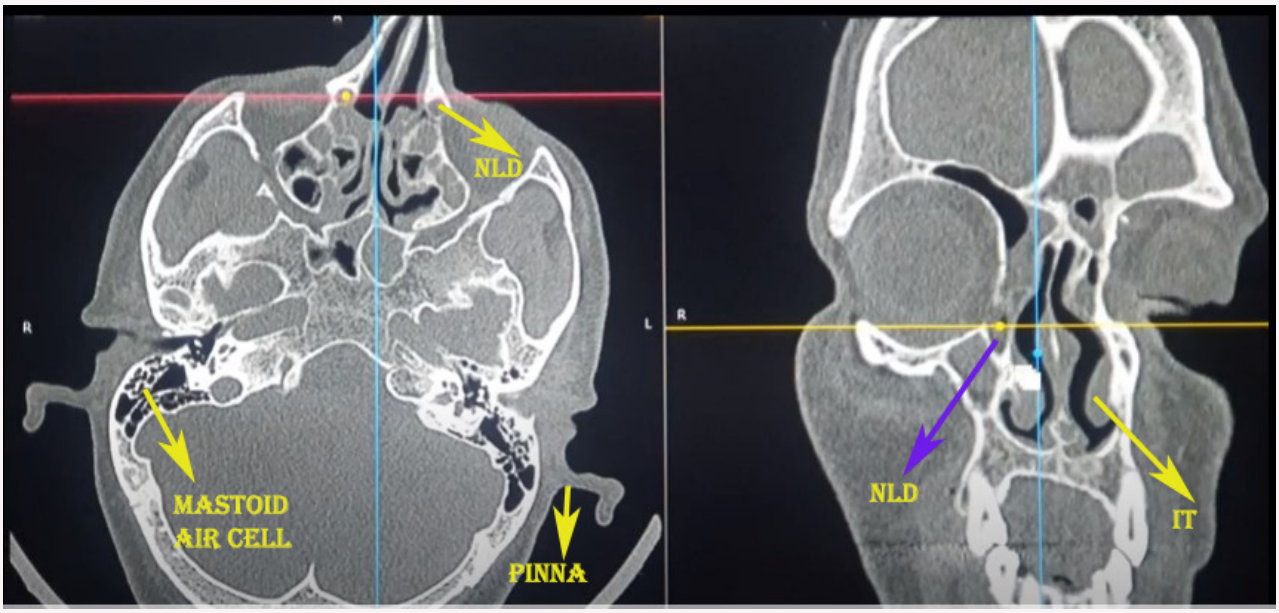


Image showing axial and corresponding coronal CT sections of nose and sinuses showing:

NLD - Nasolacrimal duct

IT - Inferior turbinante

Pinna is seen in axial cuts

Mastoid air cell system is seen in axial cut

In the axial section nasolacrimal duct is seen at the base of the frontonasal process of maxilla.

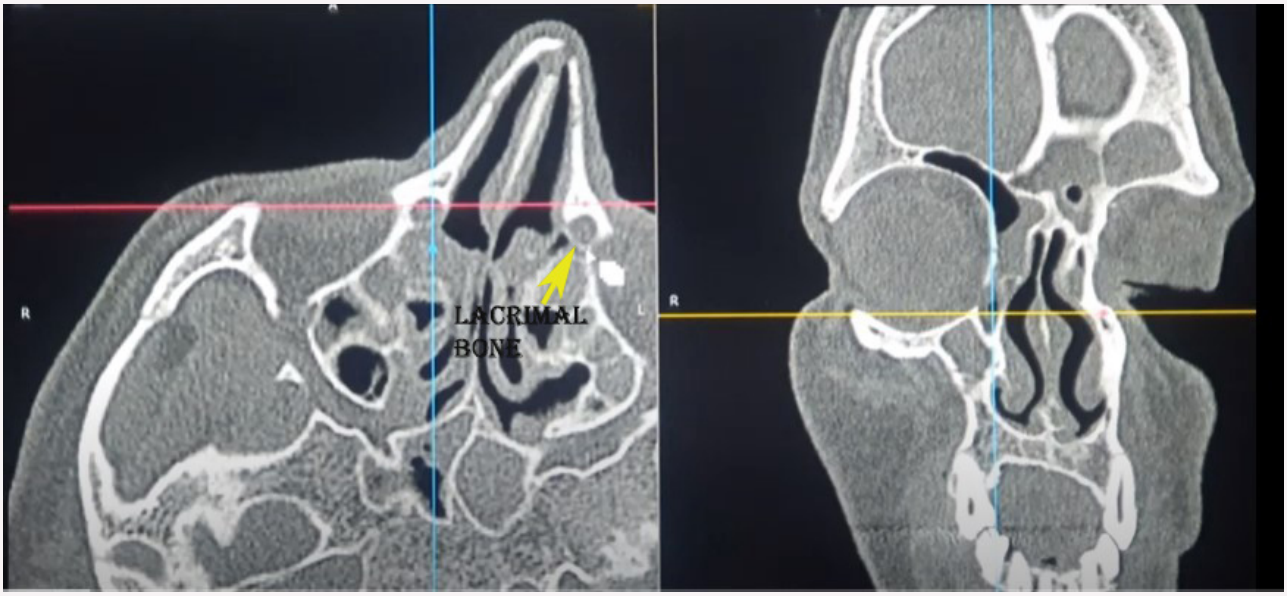


Image showing axial and corresponding coronal veiws of CT nose and sinuses. Lacrimal bone a thin piece of bone covering the posterior portion of lacrimal apparatus is clearly seen in the axial section.

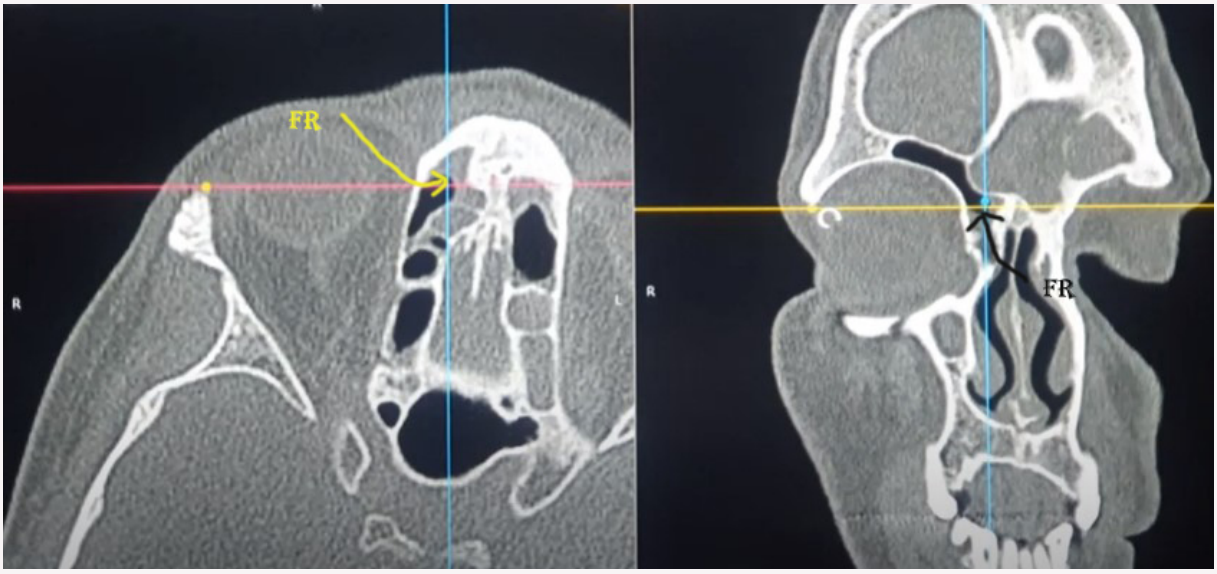


Image showing axial and coronal CT images of nose and sinuses. Black arrow in coronal section indicates frontal recess area and yellow arrow in axial cut indicates frontal recess area. Frontal recess area can be clearly seen only in coronal section. Presence of a bridge of bone between lacrimal bone and perpendicular plate of ethmoid indicates that it is frontal sinus area. If this bridge is absent then it is frontal recess area. on the right side this bridge is absent while on the left side it is present. Interfrontal sinus and frontal sinus are separated by incomplete septa.

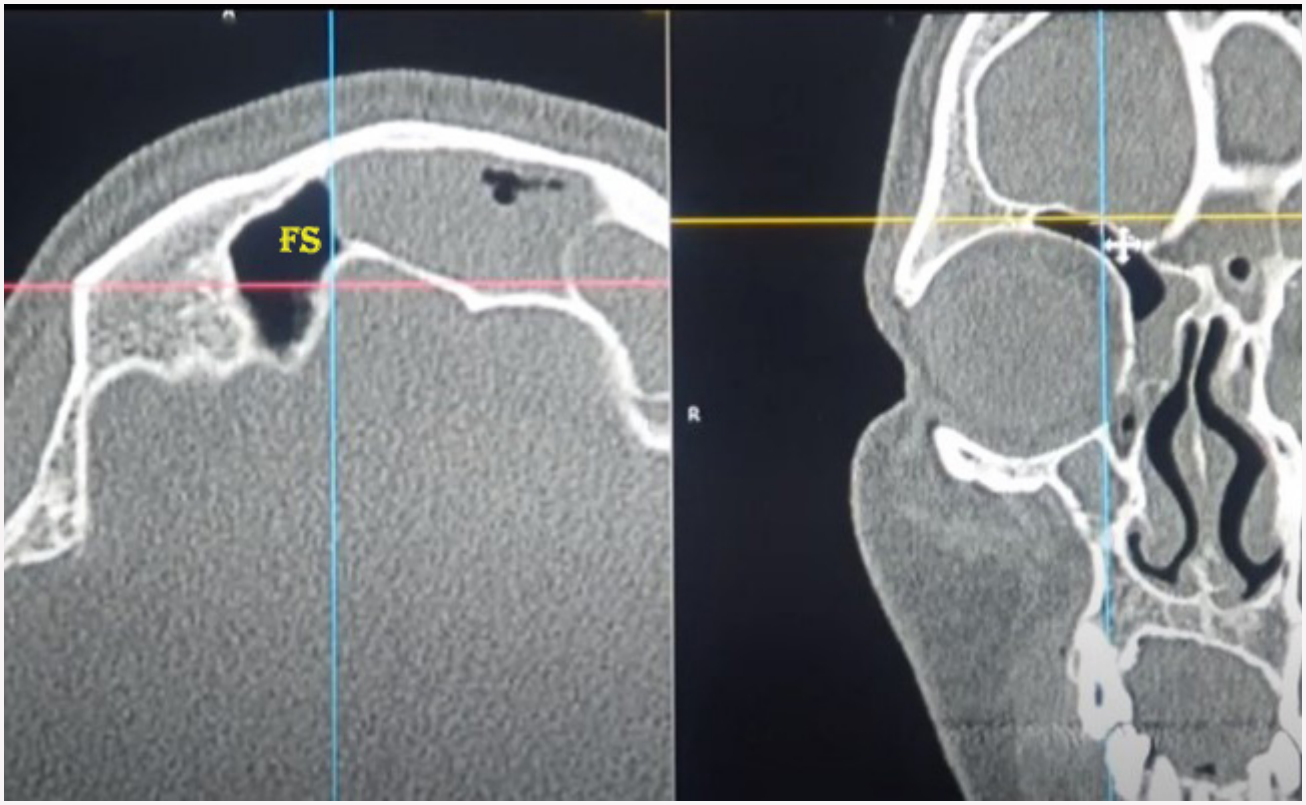


Image showing axial and coronal sections of CT nose and sinuses. In the axial section frontal sinus is marked The axial cut is taken at the level of frontal sinus.

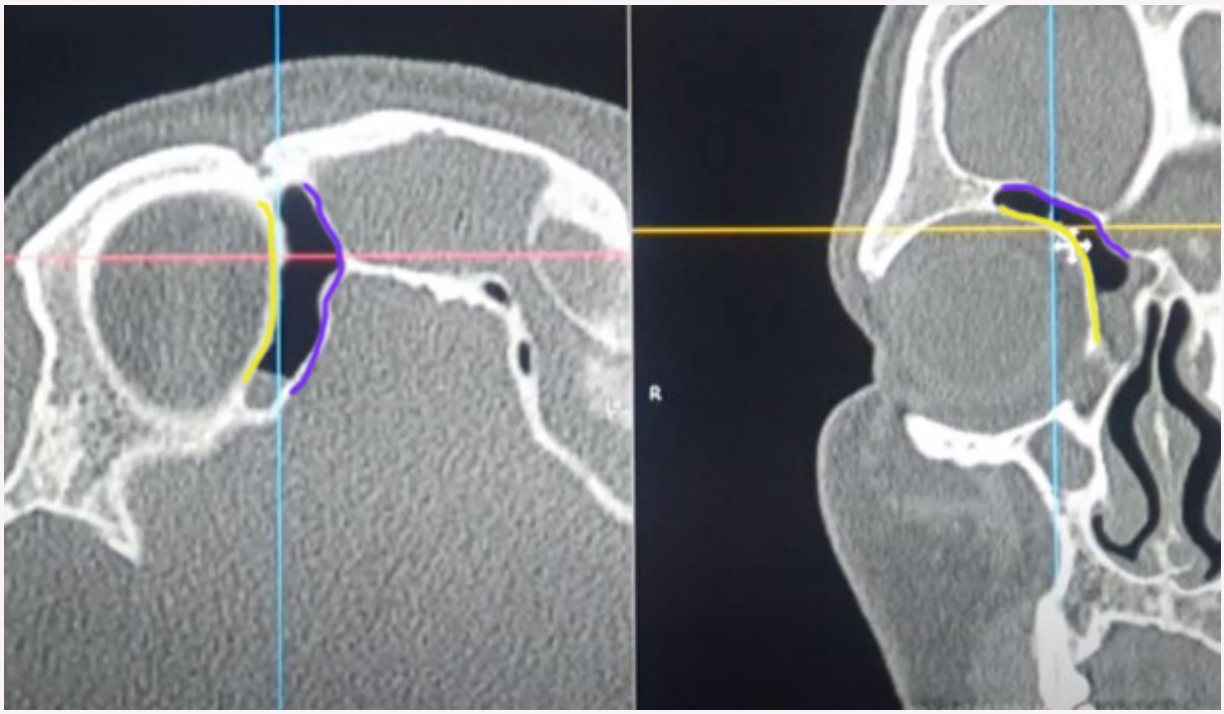


Image showing axial and coronal sections of CT nose and sinuses. Blue line marks the roof of the frontal sinus in both sections, while yellow line marks the inferior border of the frontal sinus. Note the differences in orientation between these lines in axial / coronal sections.

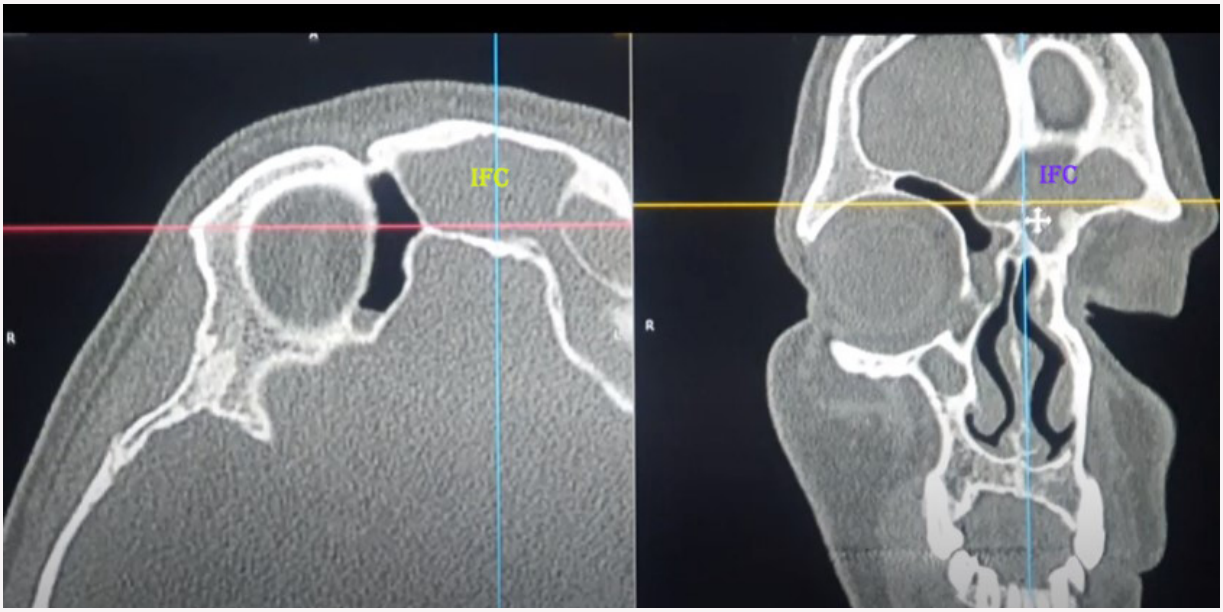


Image showing axial and coronal cuts of CT nose and sinsues showing interfrontal cell (IFC) in both of them. It can easily be identified in coronal cuts and can be identified in axial cuts easily if viewed in conjunction with coronal sections

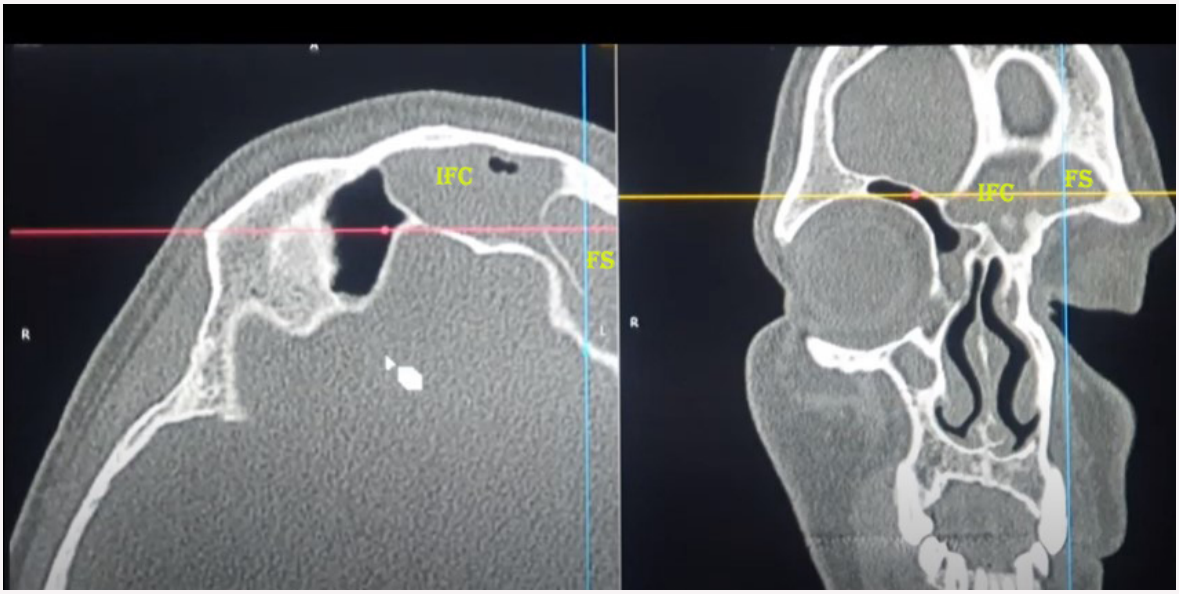


Image showing a large interfrontal cell pushing the frontal sinus laterally. This scenario is clearly evident both in axial and coronal CT images of nose and sinuses

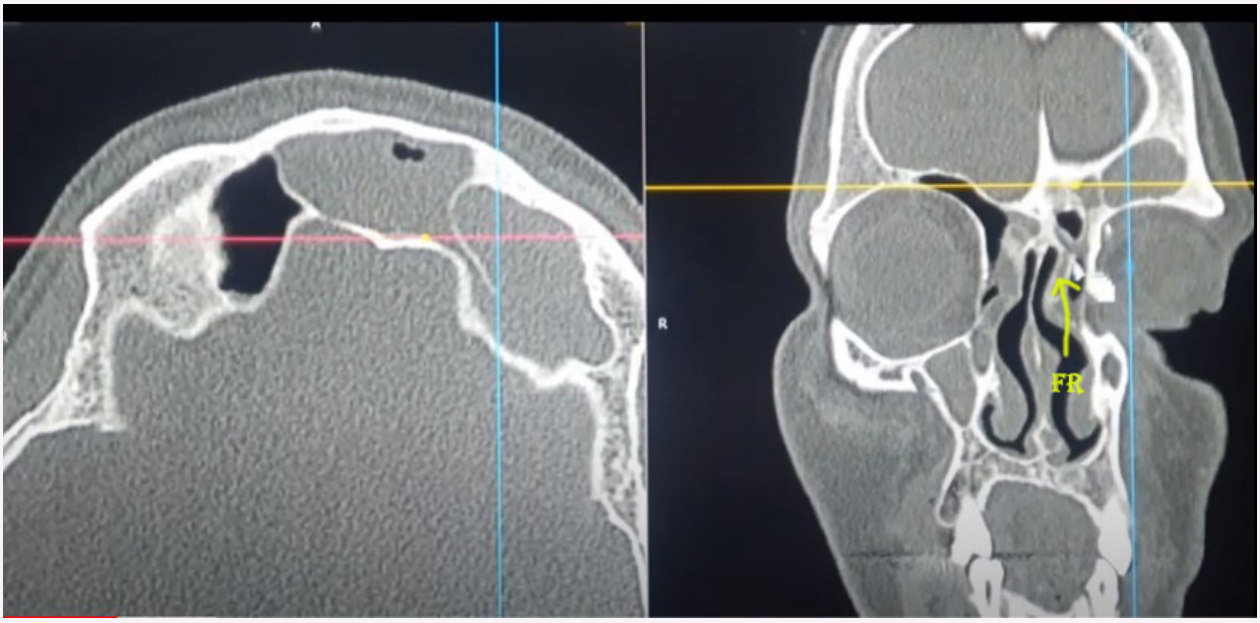


Image showing axial and coronal sections of CT nose and sinuses showing interfrontal cell draining into the frontal recess on the left side as seen in coronal cut. The same is not evident in the axial cut.

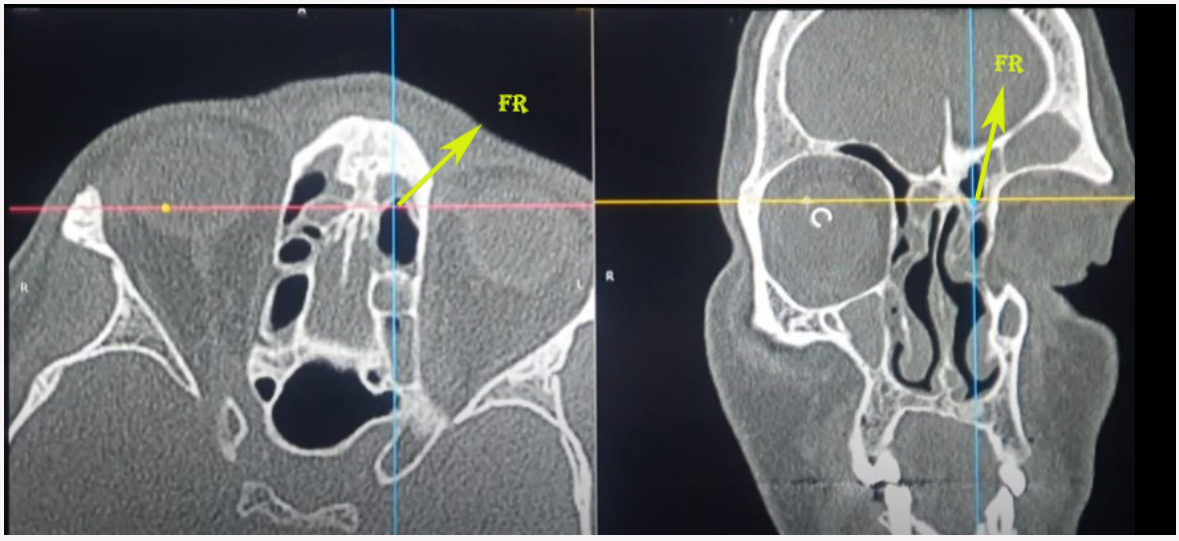


Image showing both axial and coronal CT sections of nose and sinuses showing the right frontal recess area. Comparative view as shown in both axial and coronal sections should be noted.

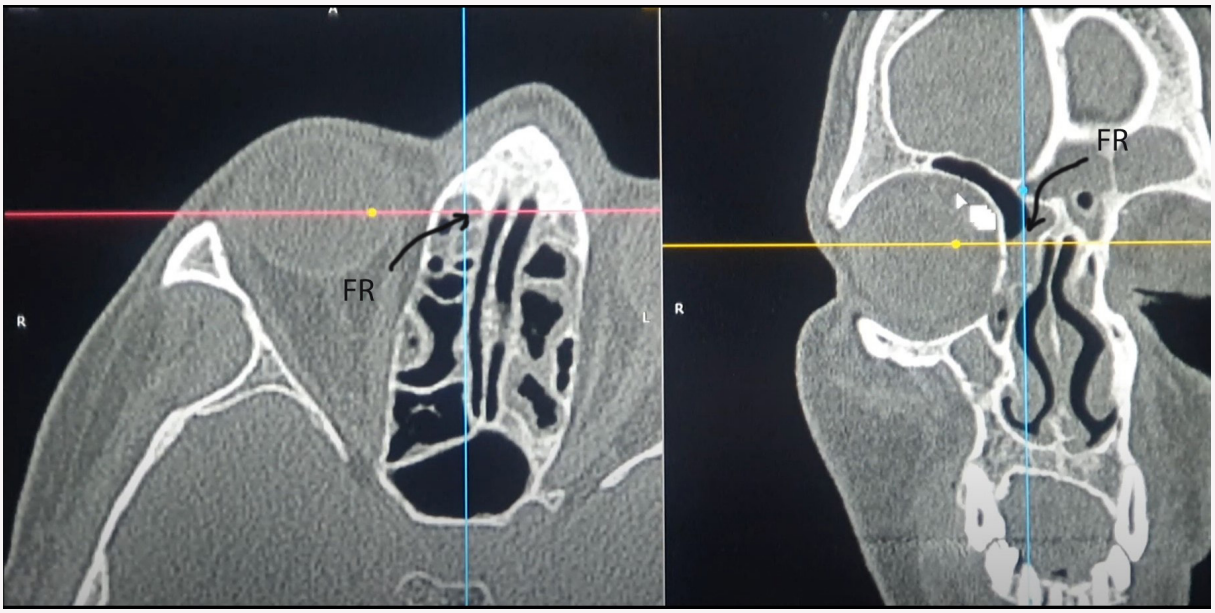


Image showing axial and coronal sections of CT nose and sinuses showing frontal recess area. As shown in the image it is pretty difficult to clearly identify this area in axial cuts without the help of corresponding coronal sections. If identified in axial cuts it will also reveal the posterior relationship of frontal recess area.

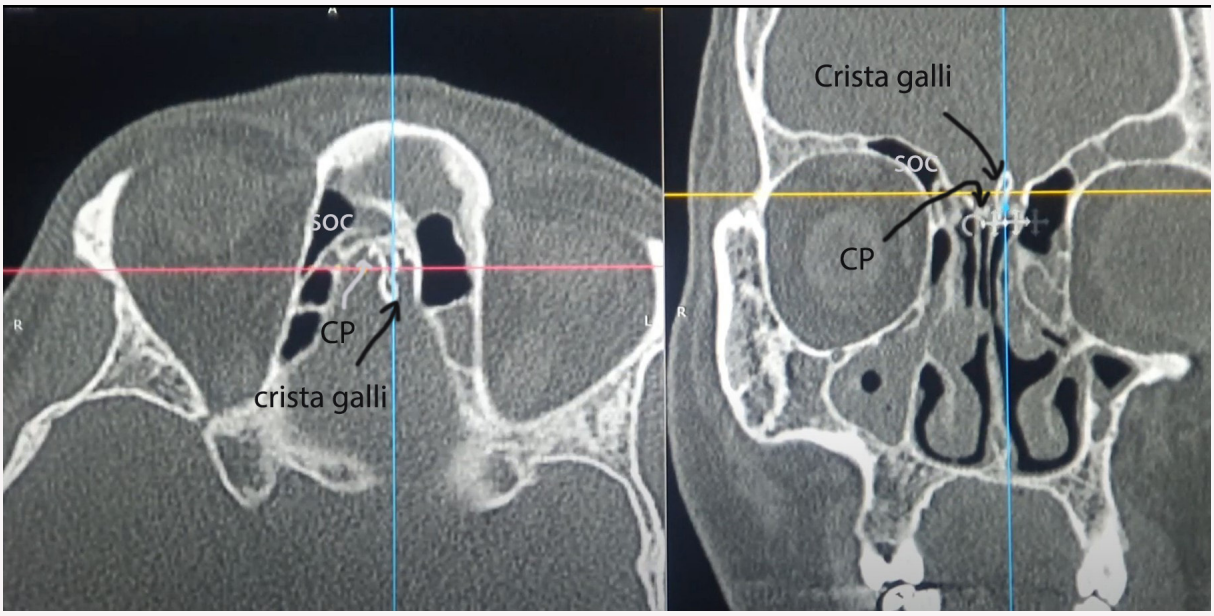


Image showing comparison between axial and coronal cuts of cribriform area. Crita galli is an important landmark. (CP - cribirform plate). Crista galli will be behind the level of frontal sinus and will not be seen at the level of frontal sinus.

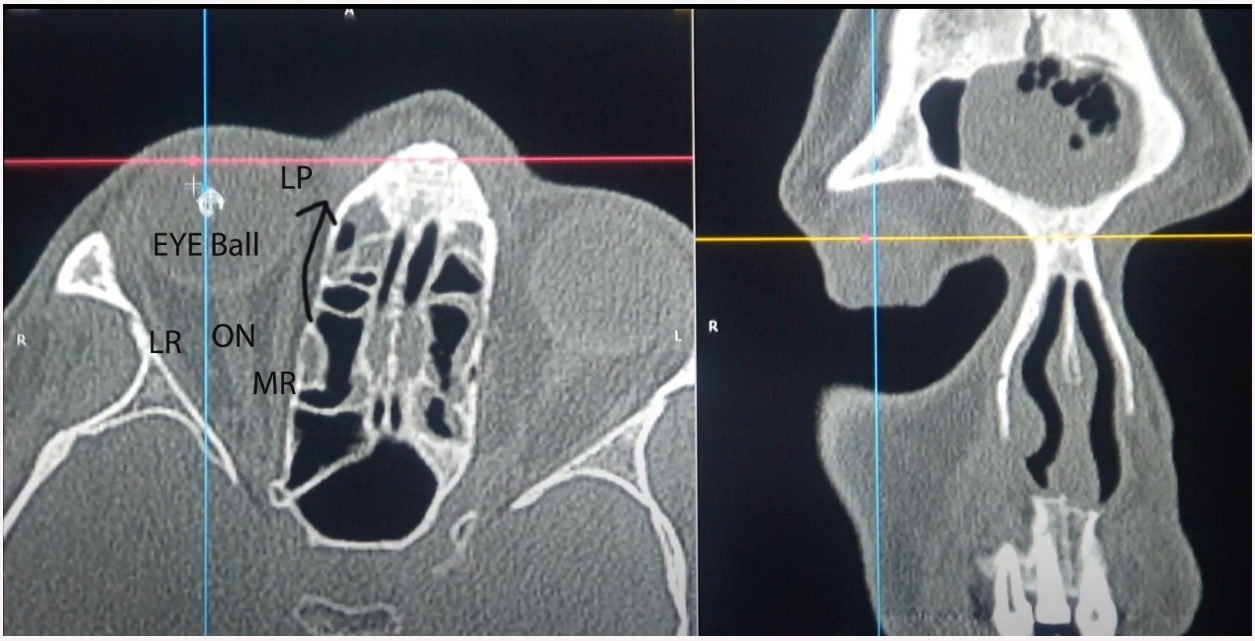


Image showing comparison between axial and coronal sections at the level of orbit. Note:

Orbit is clearlly seen in axial sections.

ON - Optic nerve

LR - Lateral rectus

MR - Medial rectus

LP - Lamina papyracea is seen in its entire extent. Erosion of lamina papyracea is clearly evident in the axial cuts.

Radiological study of orbit is incomplete without studying axial cuts of CT nose and sinuses.

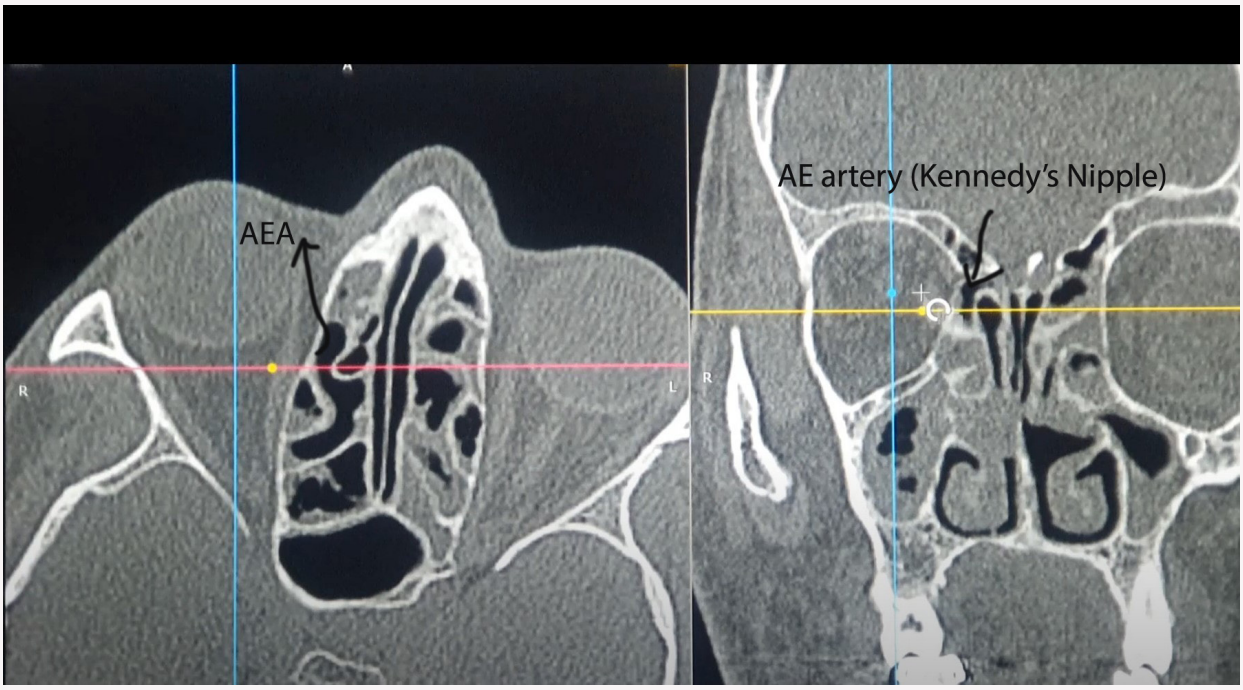


Image showing comparison between axial and coronal sections. In this image anterior ethmoidal artery is clearly seen in the cornal section in the Kennedy's Nipple area. The corresponding location of the artery is marked in the axial cut also. This image demonstrates that anterior ethmoidal artery can be clearly seen only in coronal sections

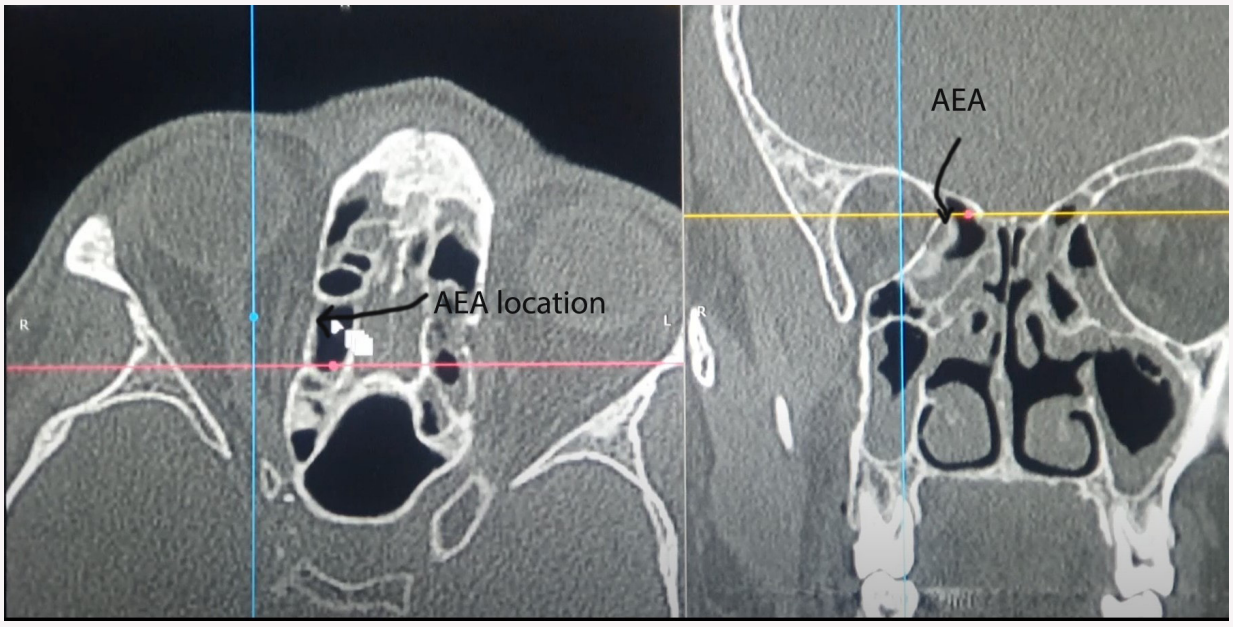


Image showing location of anterior ethmoidal artery (AEA). In the axial cut it is seen as a defect in the medial wall of the orbit as marked by black arrow.

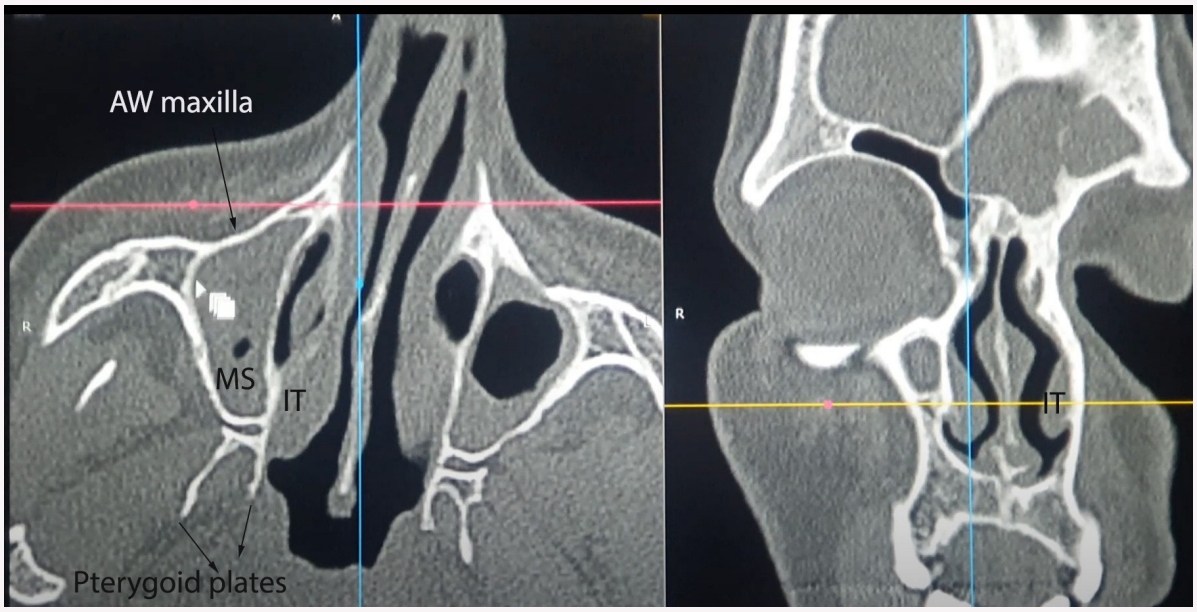


Image showing both axial and coronal CT cuts of nose and sinuses.

MS - Maxillary sinus

IT - Inferior turbinate

In axial cuts all the walls of maxillary sinus are clearly visible. Erosion of any of the walls of maxillary sinus is evident from axillary cut. Inferior turbinate is seen in its entire length.

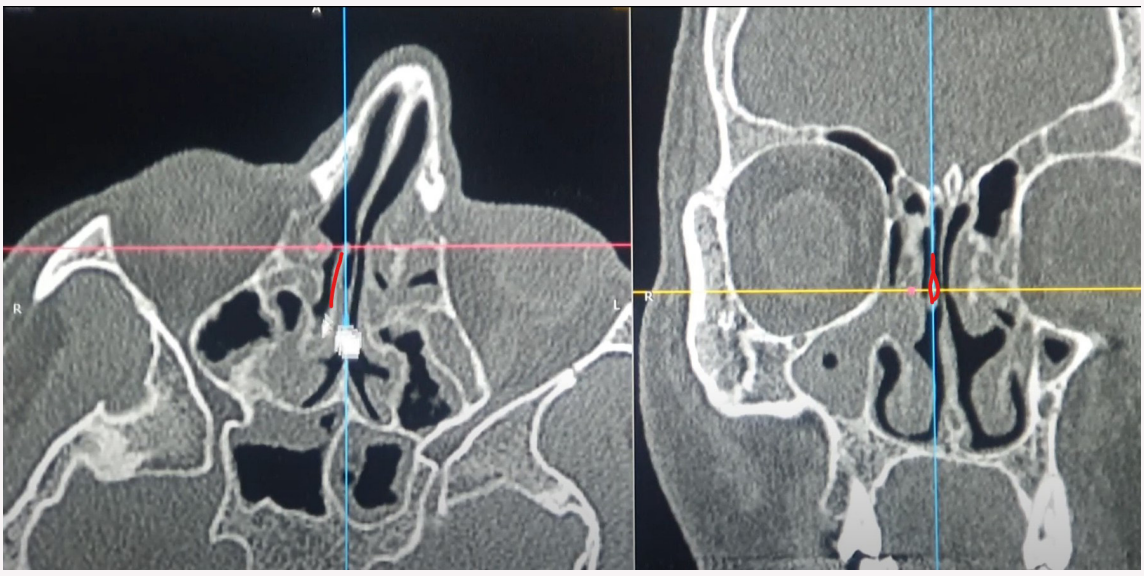


Image showing both axial and coronal sections showing the begining of middle turbinate (colored in red)

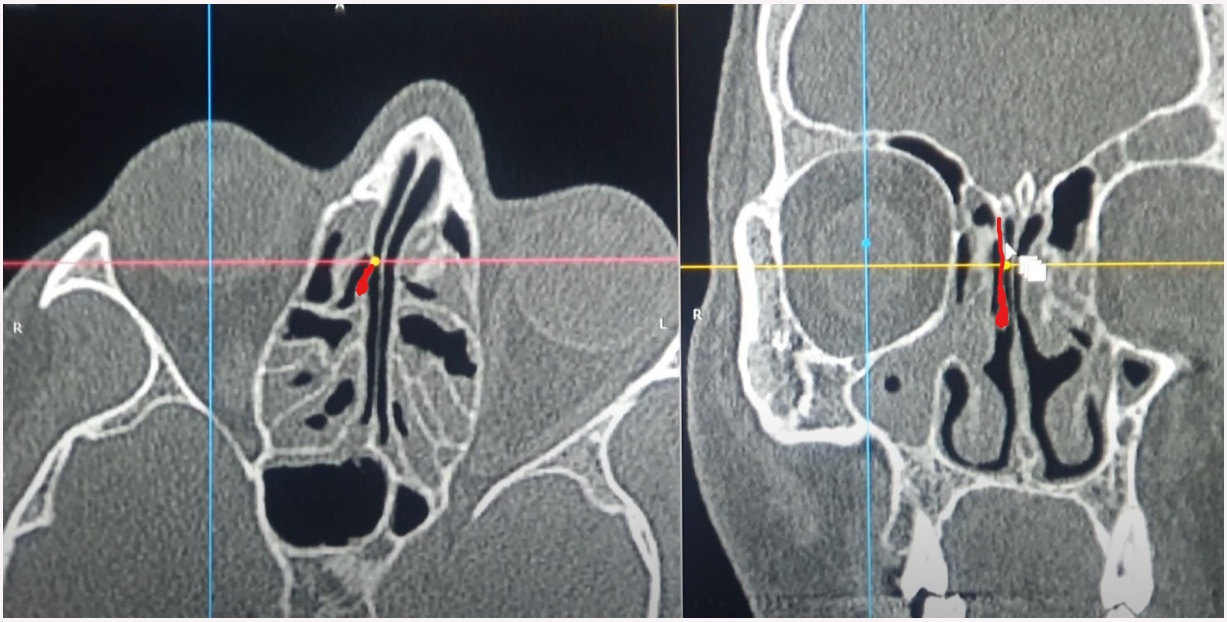


Image showing axial and coronal sections of CT nose and sinuses. Superior attachment of middle turbinate to the fovea is clearly visible on coronal view while the same area is also marked as red in axial view. Superior attachment of middle turbinate is not that evident in axial sections and it needs to be identified only in the coronal section. Anterior third of middle turbinate is always attached to the cribriform plate area. This portion of the middle turbinate always lie on the saggital plane.

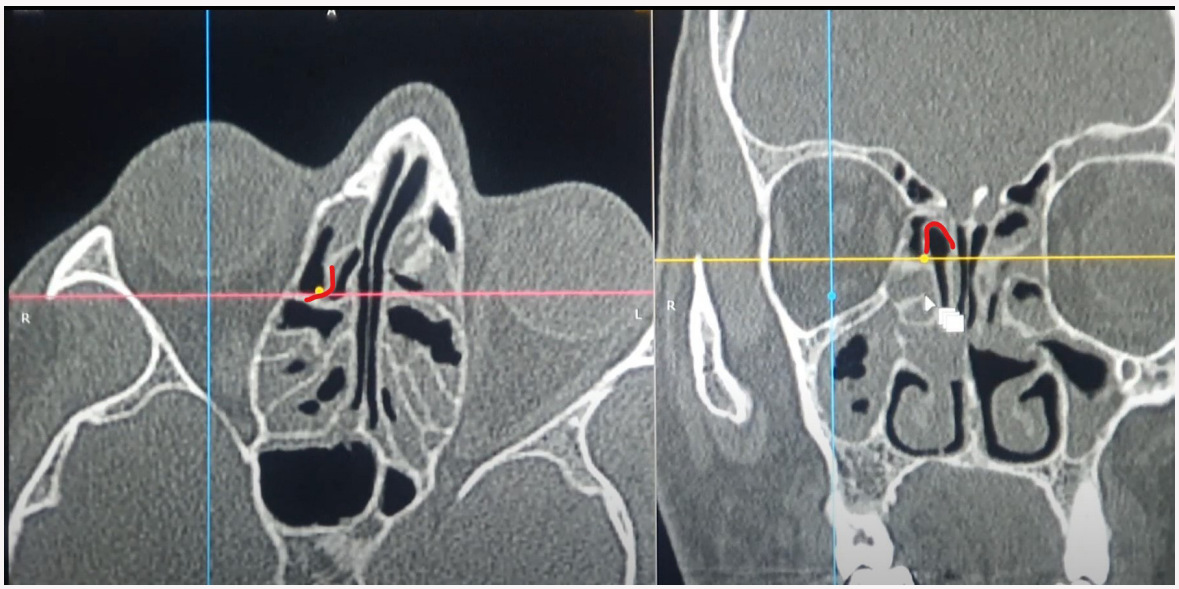


Image showing axial and coronal sections showing the lateral bend of the middle third of middle turbiante. It is indicated in red color in both the sections

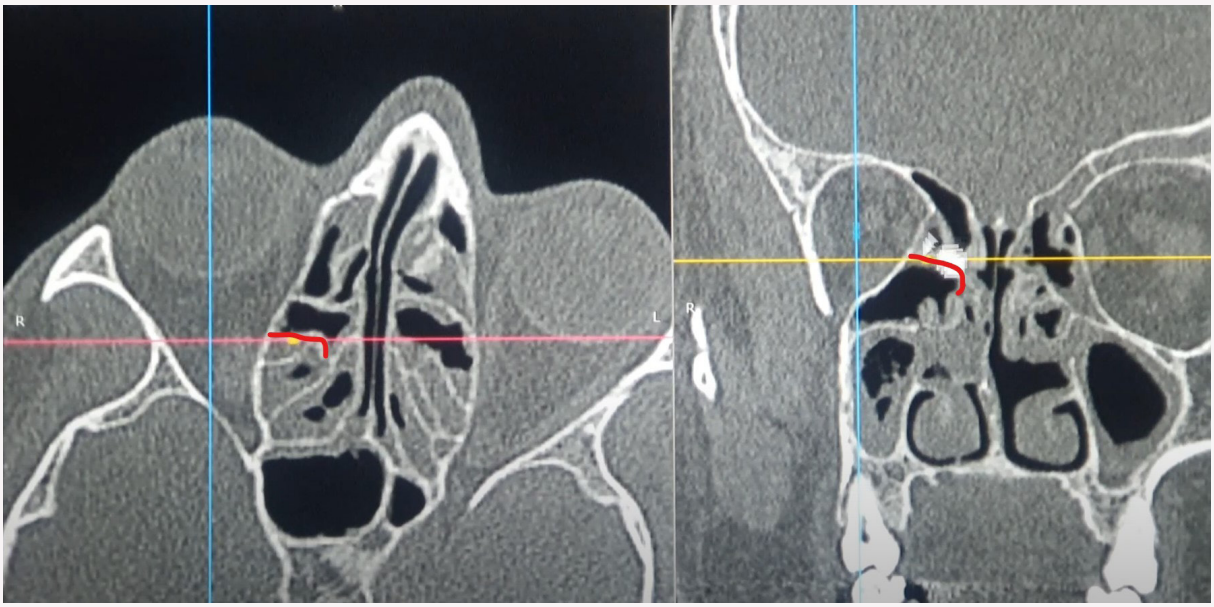


Image showing axial and coronal sections of CT nose and sinuses. Middle turbinate shows a lateral bend to get attached to the lamina papyracea. Indicated in red color line in both cuts. This portion is the middle portion of the middle turbinate and is also known as the ground lamella that seperates both the anterior and posterior ethmoidal cells. Cells lying in front of ground lamella is the anterior ethmoid group while those cells that lie behind ground lamella forms the posterior ethmoidal group of ethmoid air cells.

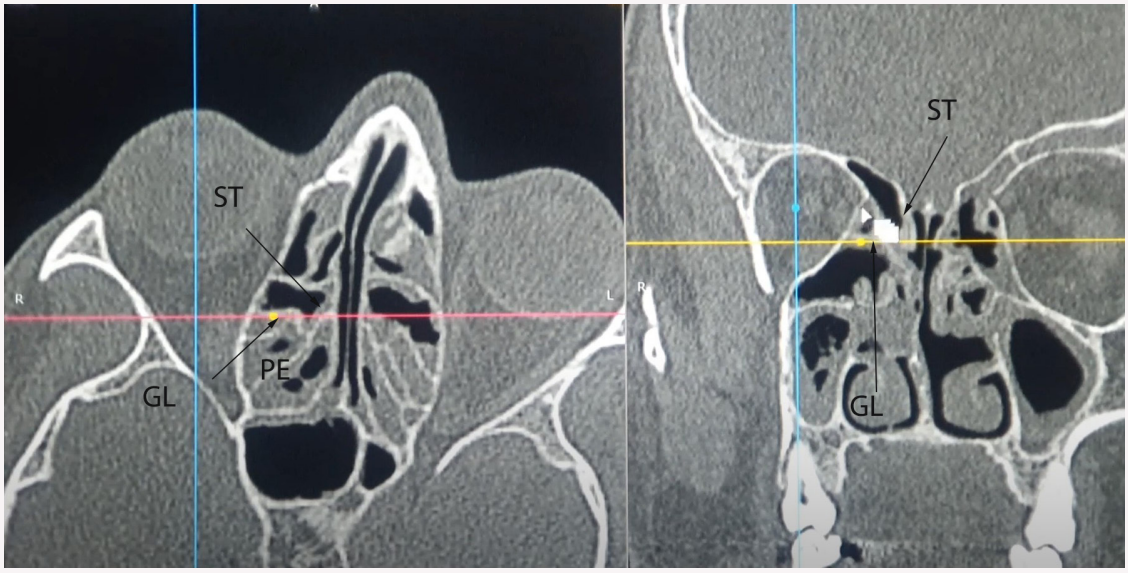


Image showing axial and coronal section of CT nose and sinuses showing basal lamella (GL) Suprior turbinate which forms the medial border of posterior ethmoid air cells and PE (posterior ethmoid air cells)

Basal lamella can easily be identified by correlating axial and coronal images so that there is no confusion regarding the location of this structure. During endosopic sinus surgery procedures basal lamella (ground lamella) forms an important landmark for the surgeon to distinguish the transition point where anterior ethmoidal air cells end and posterior ethmoid air cells begin. Air cells in front of this basal lamella belong to the anterior ethmoidal group and air cells behind this lamella belongs to the posterior ethmoid group. Anterior ethmoidal air cells drain via the middle meatus while the posterior ethmoidal air cells drain via the sphenoethmoidal recess area.

Parson's ridge:

Attachment of superior turbinate to sphenoid face is critical in determining entry into sphenoid. There are 4 typs of Parson's ridge:

Type A - Superior turbinate attachment is in medial 1/3.

Type B - Superior turbinate attachment is in middle third.

Type C - Superior turbinate attachment is attached in the lateral third.

Type D - Superior turbinate attachment is to the orbit

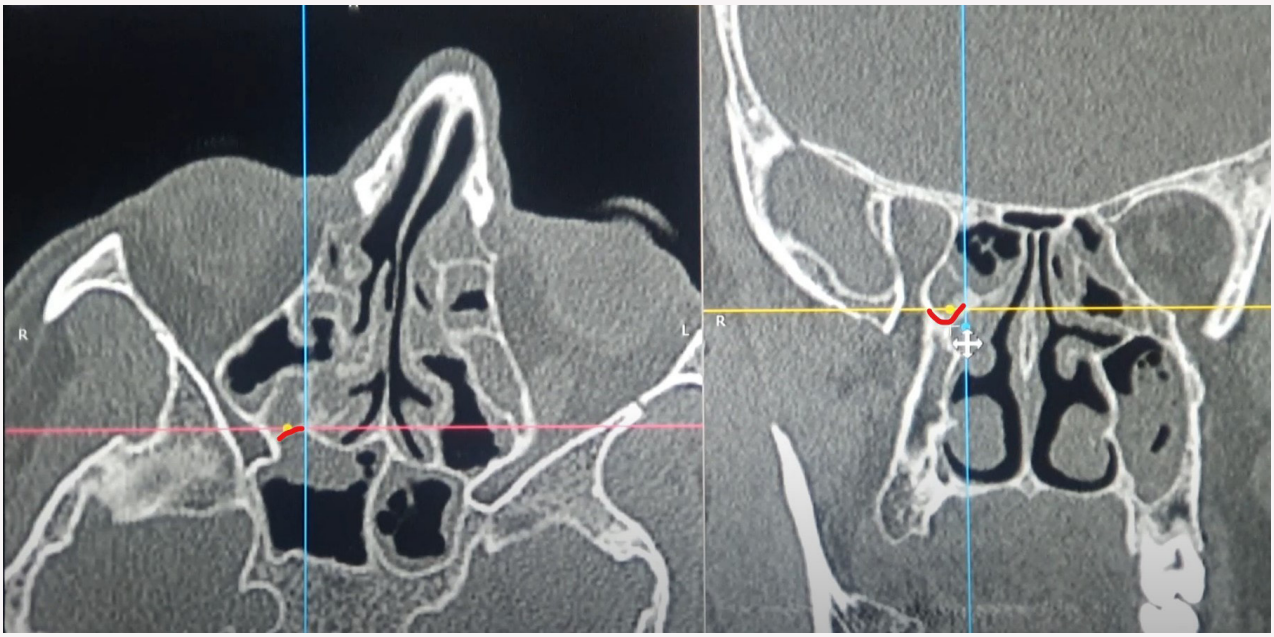


Image showing the third part of middle turbinate getting attached to the perpendicular plate of palatine bone. This is indicated by red curved line in axial and coronal sections of CT nose and sinuses

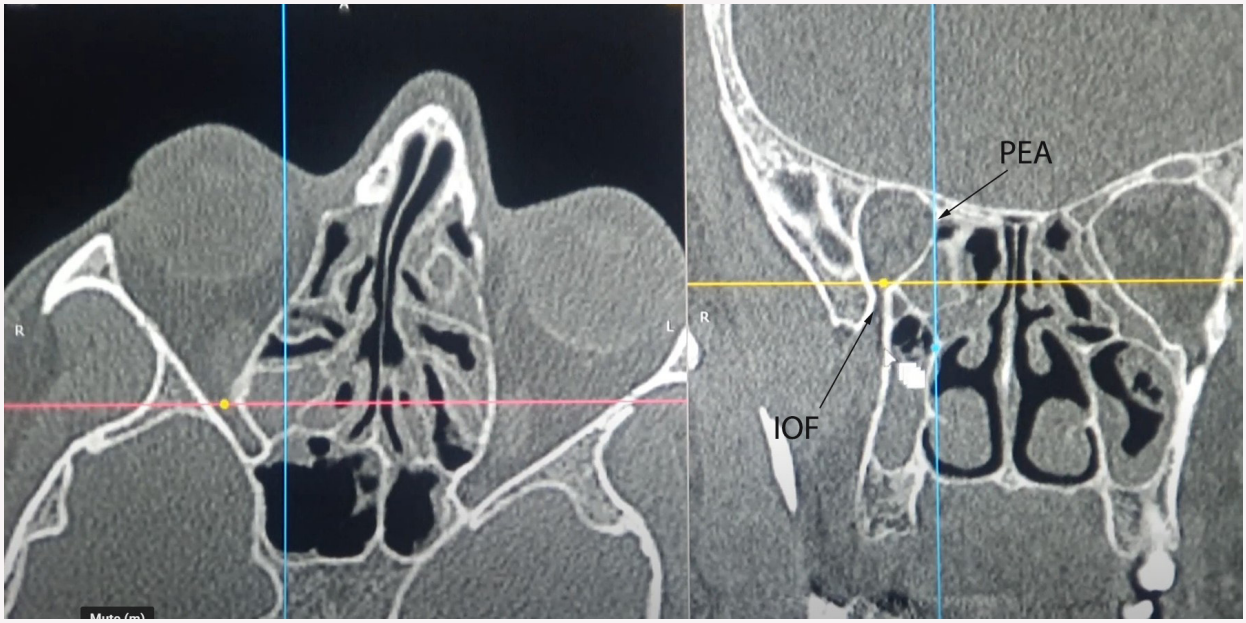


Image showing axial and coronal CT nose and sinuses showing:

PEA - Posterior ethmoidal artery

IOF- Inferior orbital fissure

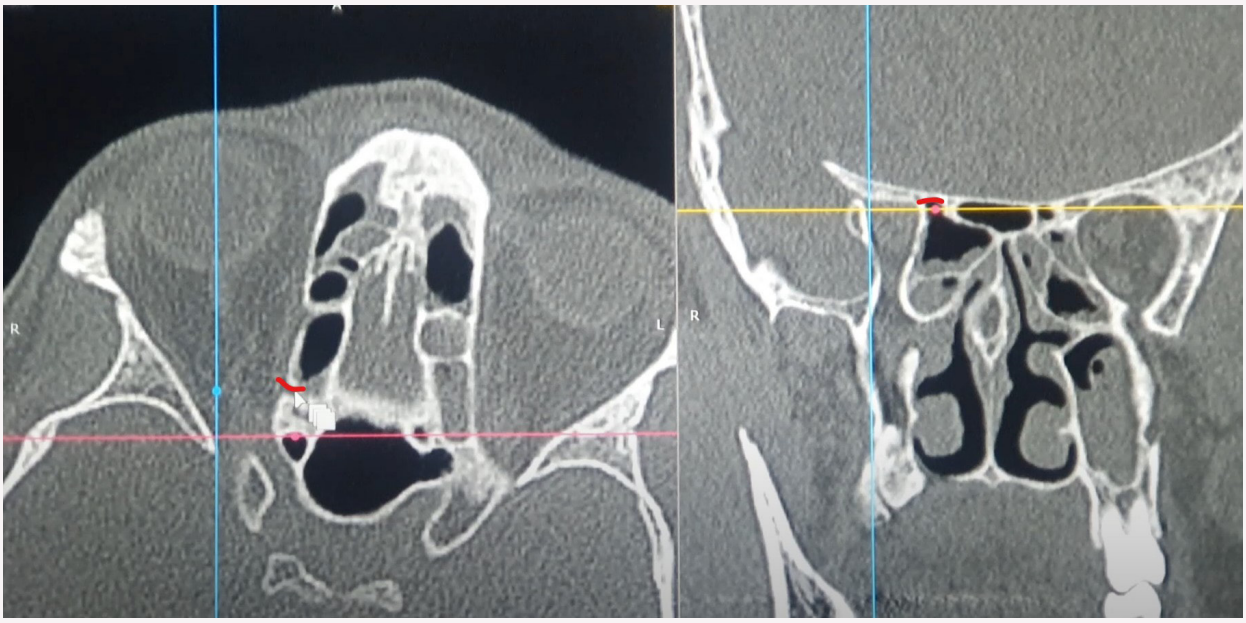


Image showing the location of posterior ethmoidal artery in axial and coronal cuts (red color)

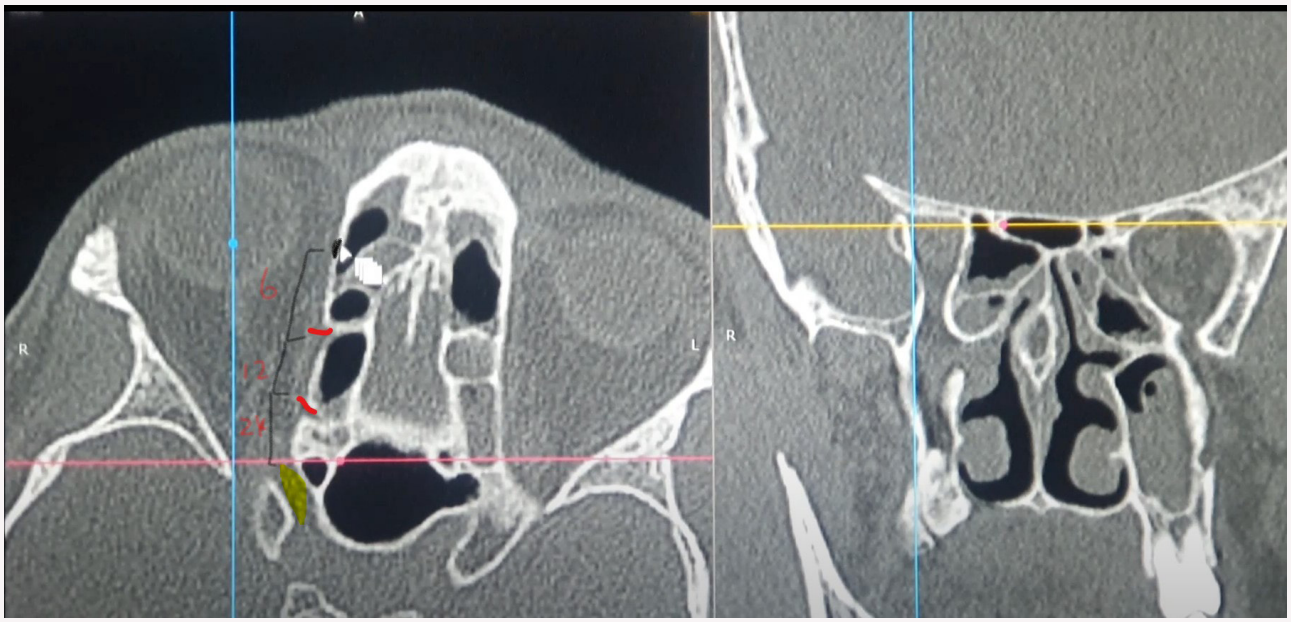


Image of axial and coronal sections of CT nose and sinuses showing the 6,12, 24 rule.

Distance between anterior lacrimal crest to anterior ethmoidal artery - 24 mm

Distance between anterior ethmoidal and posterior ethmoidal artery - 12 mm

Distance between posterior ethmoidal artery and optic nerve - 6 mm

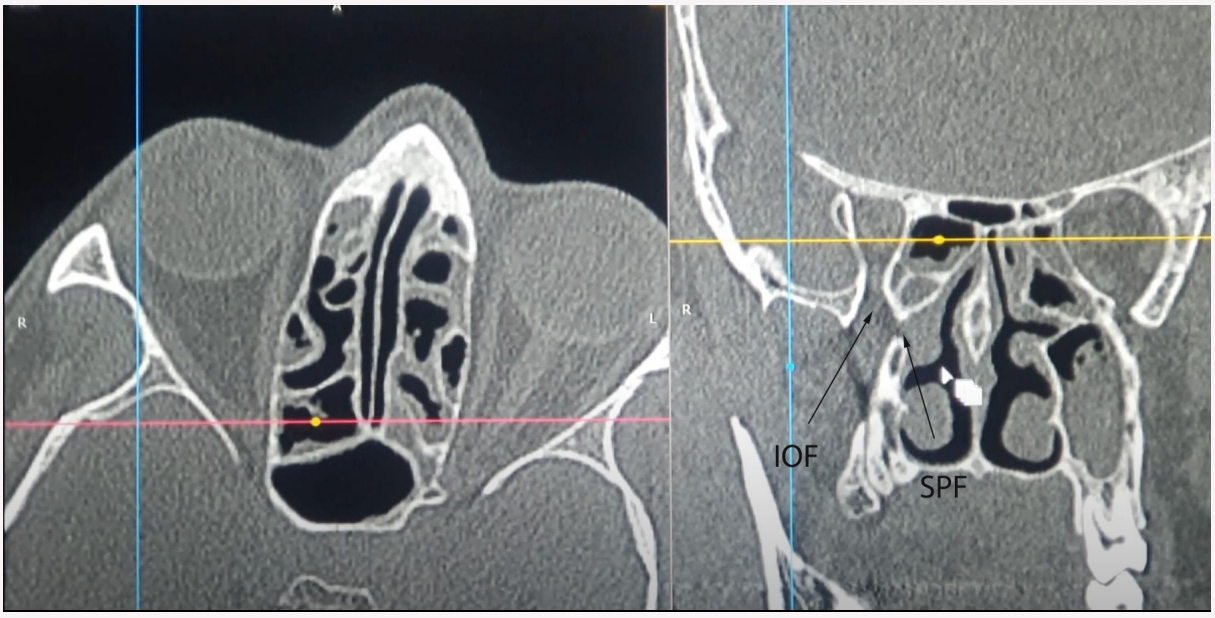


Image showing the relationship between IOF - inferior orbital fissure and SPF - Sphenopalatine foramen

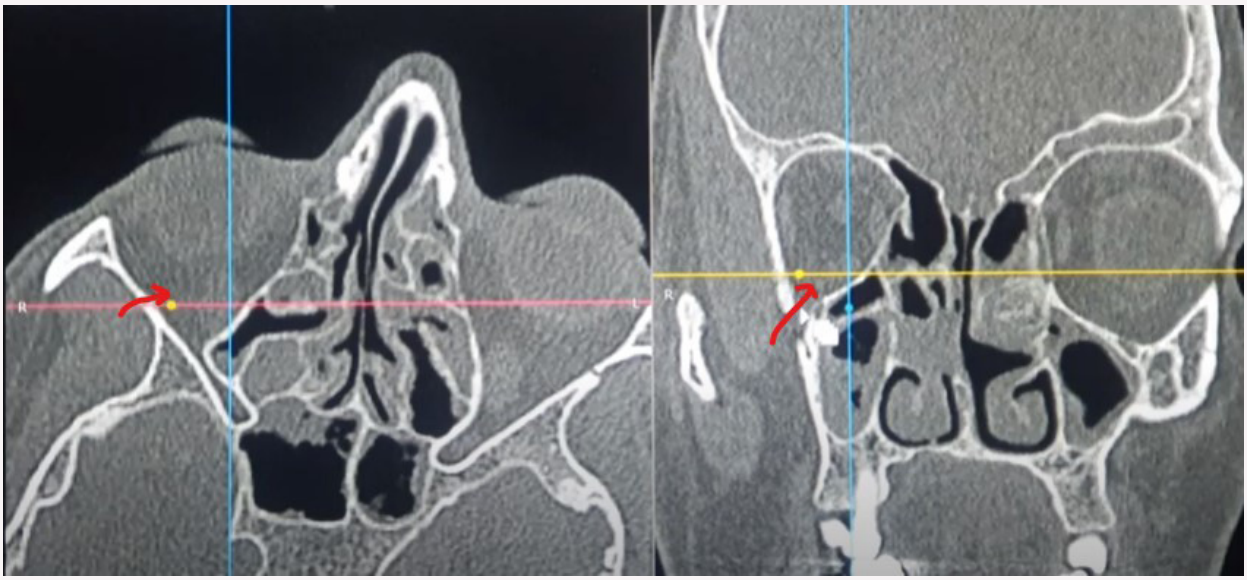


Image showing the inferior orbital fissure. Please note the location of this fissure in both axial and coronal cuts. It should be stressed that it is easy to visualize in coronal section and can be visualized in axial section if viewed in conjunction with coronal section.

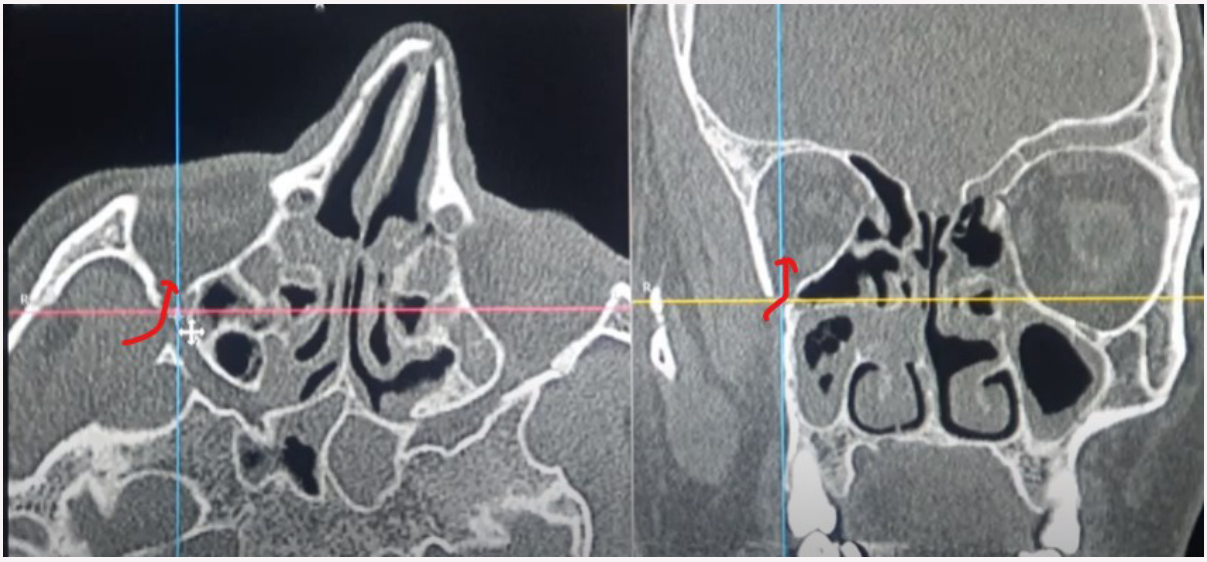


Image showing axial and coronal CT of nose and sinsues showing the location of inferior orbital fissure. In this cut inferior orbital fissure is clearly visible even in axial cuts. In Patients with JNA it invades the orbit via the inferior orbital fissure.

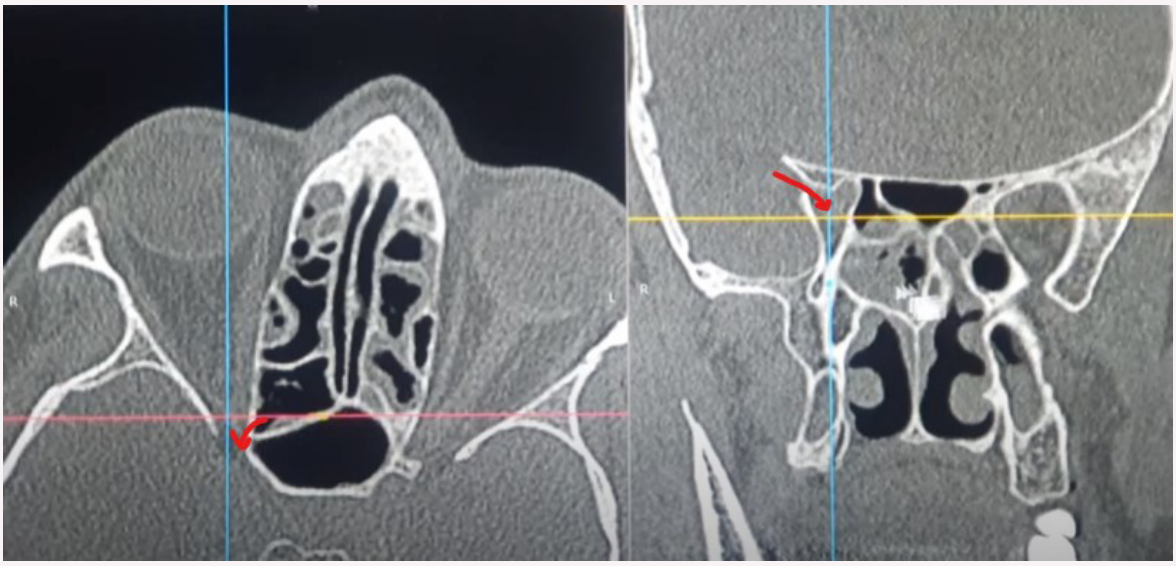


Image showing axial and coronal sections of CT nose and sinuses. Superior orbital fissure is clearly seen in coronal cut (red arrow). The same is marked in the axial cut also.

Superior orbital fissure is the anterior continuation of cavernous sinus. This should clearly be understood

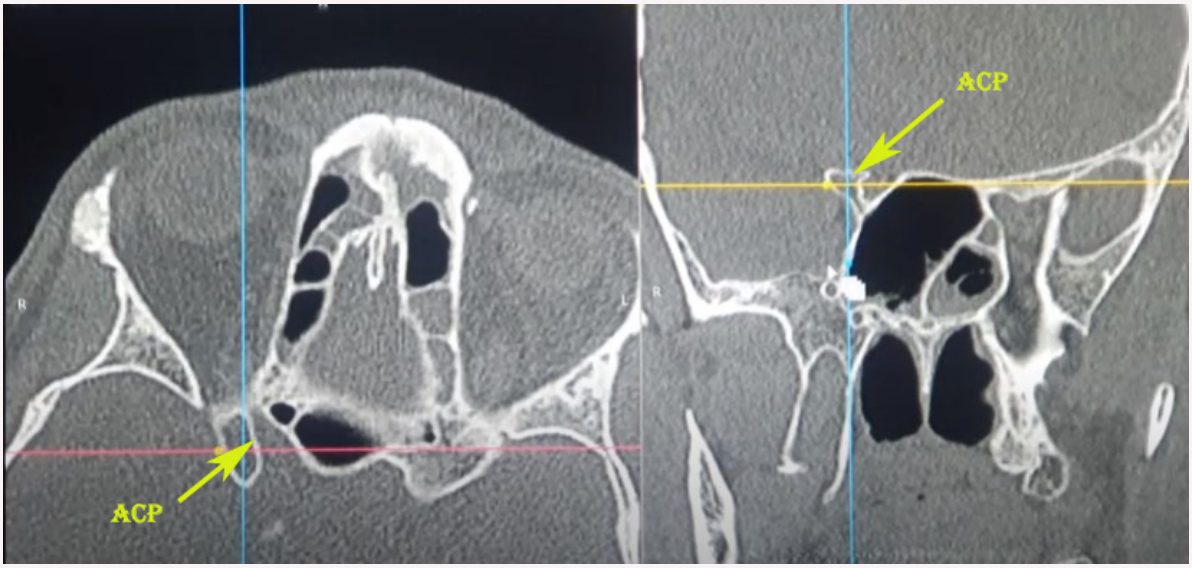


Image showing axial and coronal sections of CT nose and sinuse showing anterior clinoid process (ACP). This part belongs to the lesser wing of sphenoid bone

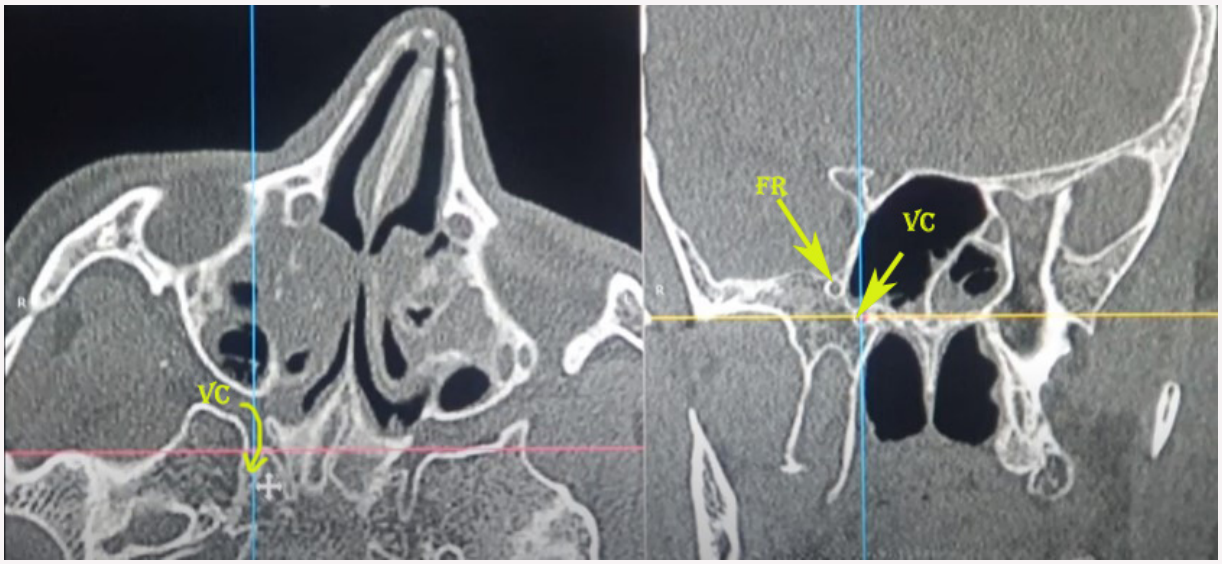


Image showing both axial and coronal sections of CT nose and sinuses showing

VC - vidian canal. This is an important landmark for the location of internal carotid artery in anterior skull base surgery. Vidian canal can be traced posteriorly to locate the internal carotid artery.

FR - Foramen rotendum

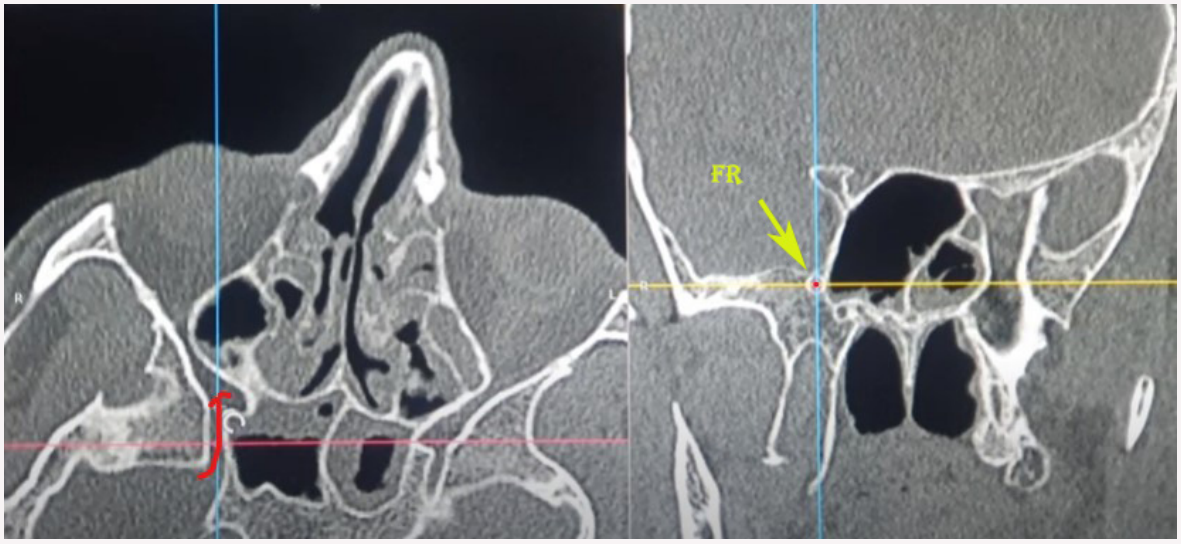


Image showing both axial and coronal cuts of CT nose and sinuses. It shows FR-foramen rotendum. Red arrow in axial cut

Foramen rotendum contains the maxillary nerve which traverses it to reach the posterior portion of pterygopalatine fossa. This nerve enters the orbit and exits it via the infraorbital fissure as infraorbital nerve.

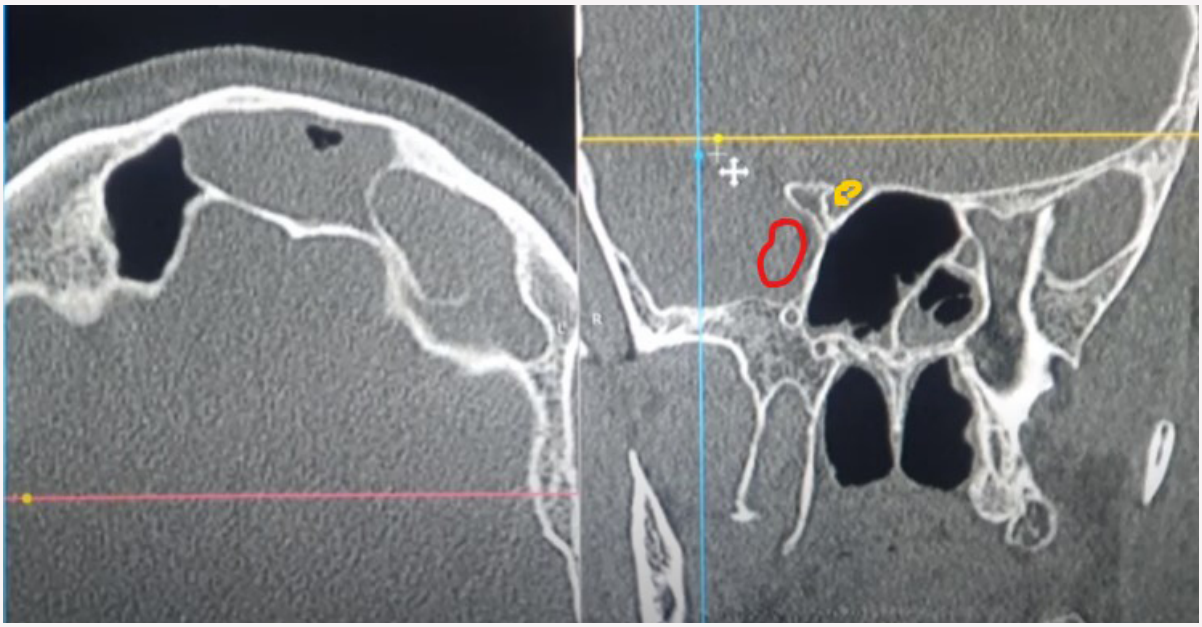


Image showing axial and coronal cuts of CT nose and sinuses. In the coronal seection optic nerve is seen as yellow circle and carotid bulge is seen in the lateral wall of sphenoid (red circle).

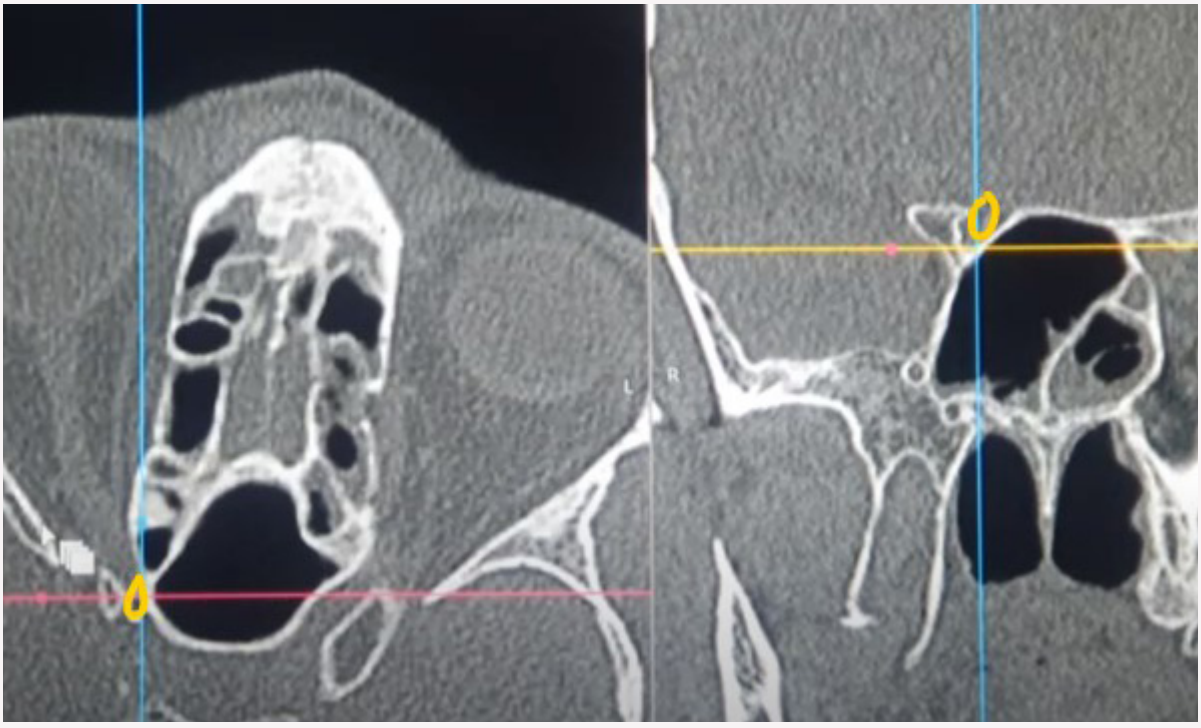


Image showing position of optic nerve in both axial and coronal cuts (Yellow circle)

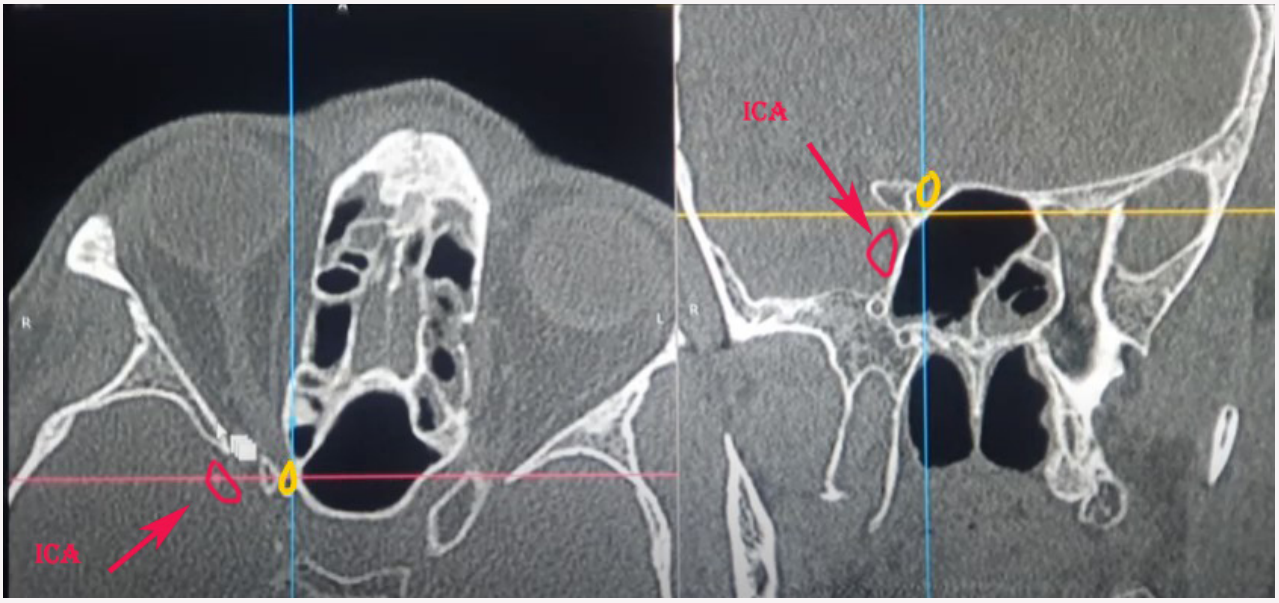


Image showing axial and coronal cuts of CT nose and sinuses showing the location of internal carotid artery (red circle) and optic nerve (yellow circle). Note their relationship with that of the lateral wall of sphenoid sinus. Vidian canal is always medial to the carotid artery in this cut.

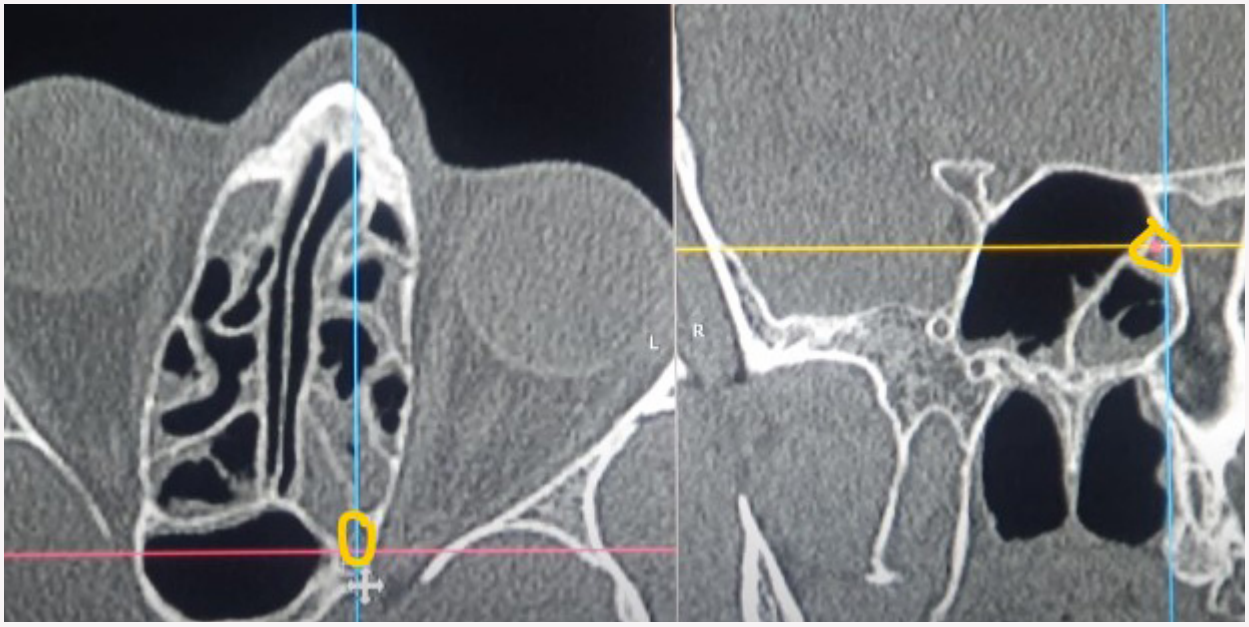


Image showing axial and coronal sections of CT nose and sinuse showing onodi cell. (Yellow circle). Note its relative positions in both these cuts. Right sphenoid sinus is larger and dominant than the left one. Onodi cell is seen in this patient on the left side. The relationship of onodi cell with optic nerve is clearly seen in axial sections

if onodi cell is present then this could be an important landmark for optic nerve. If onodi cell is present then optic nerve decompression can be performed by opening up this cell via the sphenoid. There is also a flip side to the presence of onodi cell. Inexperienced surgeon could traumatize the optic nerve if it is naked and lies within the onodi cell. Inflammation involving onodi cell could affect the optic nerve if it lies naked within it.

Onodi cell is considered to be part of posterior ethmoidal air cell even though it lies close to the sphenoid sinus. It is also known as sphenoethmiodal air cell.

Sagittal CT Nose and Sinuses Anatomy & comparison with coronal images

In the axial view sinus cavities are imaged from top to bottom. This view is taken by asking the patient to keep their hard palate perpendicular to the scanning table. Frontal sinus outflow tract can be extensively studied in sagittal sections. Sagittal images also displays the drainage of anterior ethmoidal air cells into the middle meatus and posterior ethmoid air cells into the sphenoethmoidal recess. In this chapter various anatomical sructures that are visible in sagittal sections will be descibed using CT images cut by cut. The type of pneumatization of sphenoid sinus can be studied efficiently in sagittal scans.

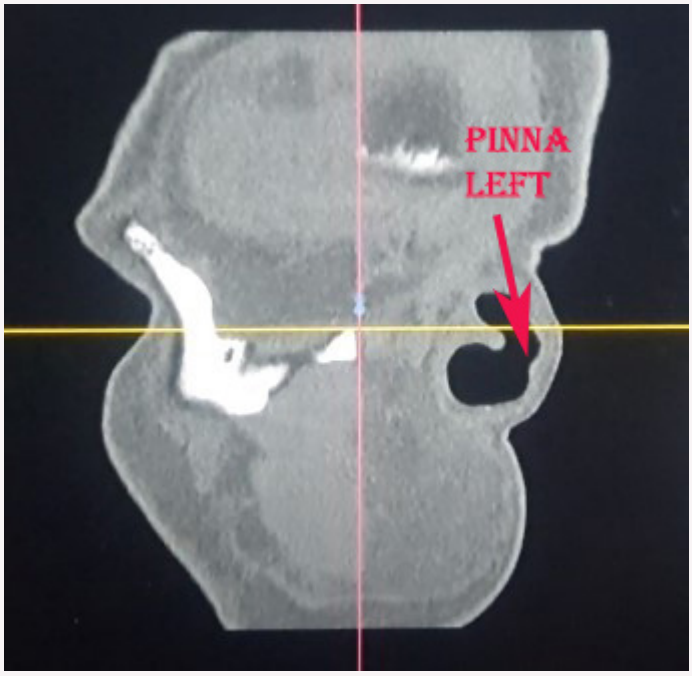


Image showing Sagittal cut of CT nose and sinuses. The side imaged can be ascertained only after viewing the cut in which pinna is visible as shown above. It is the left pinna and hence the cut is from the left side.

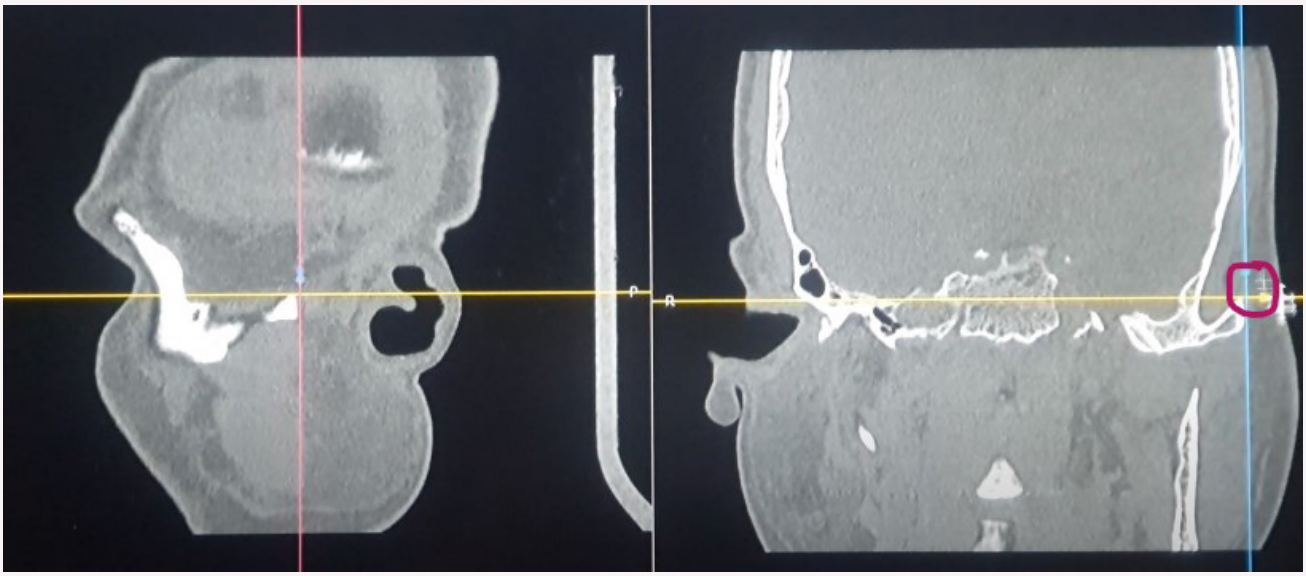


Image showing the comparison between sagittal and coronal sections. Pink circle indicates the exact area in which the cut is made. Commonly sagittal sections are made from left to right. But the side should be commented only after viewing the pinna in the cut or after comparing the cut with that of coronal cuts

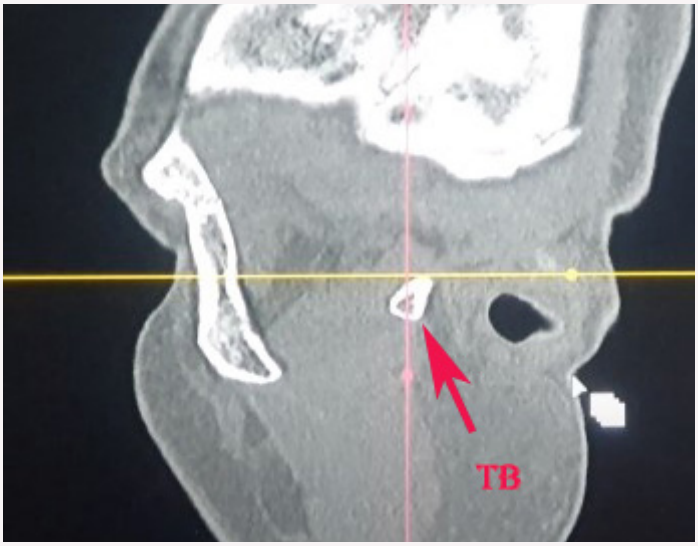


Image showing the emergence of temporal bone. Pinna slowly vanishes. As the cut progresses gradually towards the right side, temporal bone begins to appear first followed by the pinna.

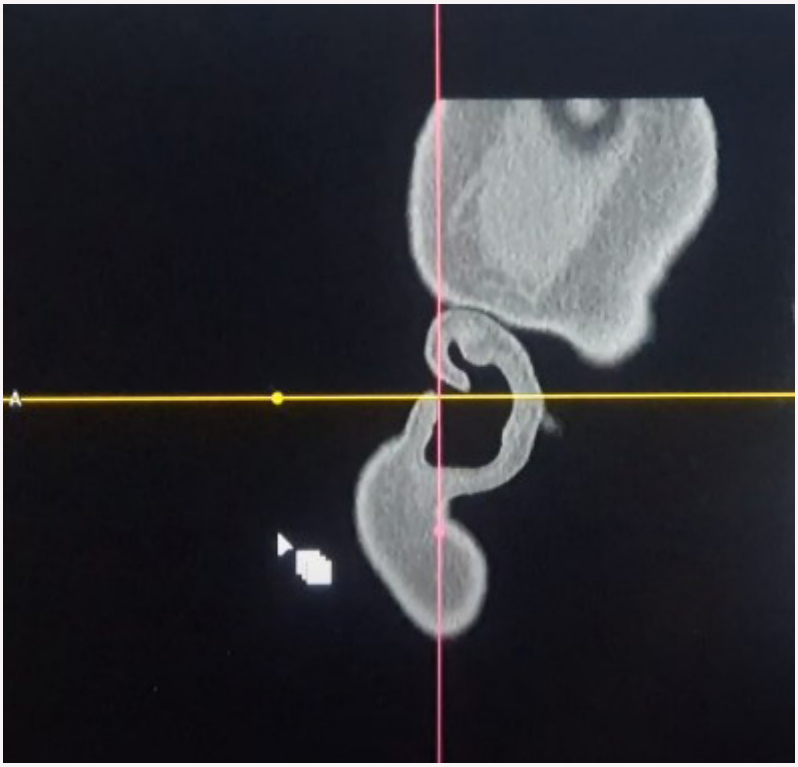


Image showing sagittal section CT of nose and sinuses showing right pinna

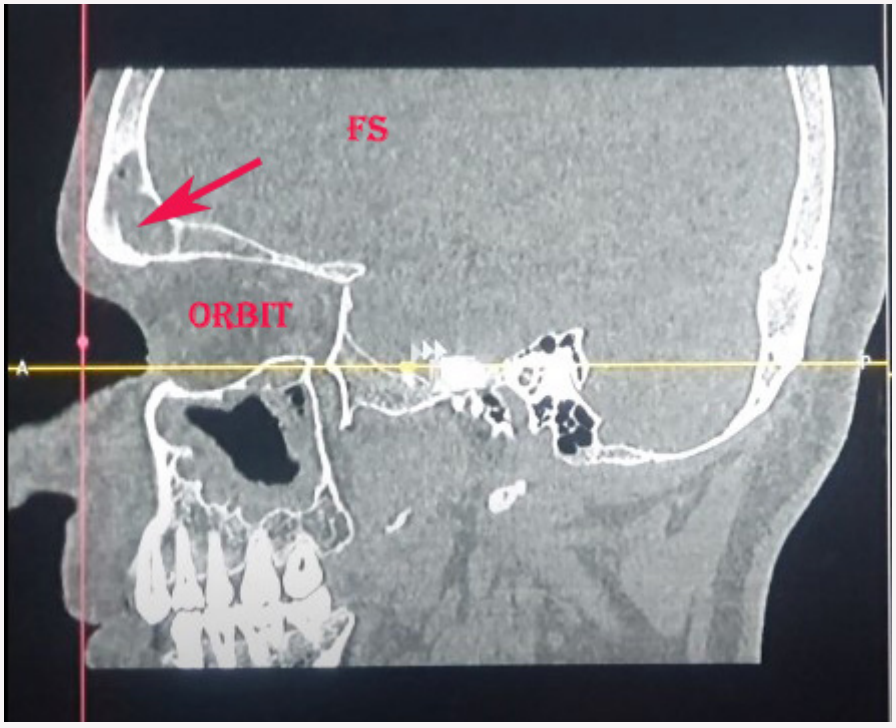


Image showing sagittal section of nose and sinuses showing:
FS - Frontal sinus (both anterior and posterior table are visible)
Orbit
Maxillary sinus

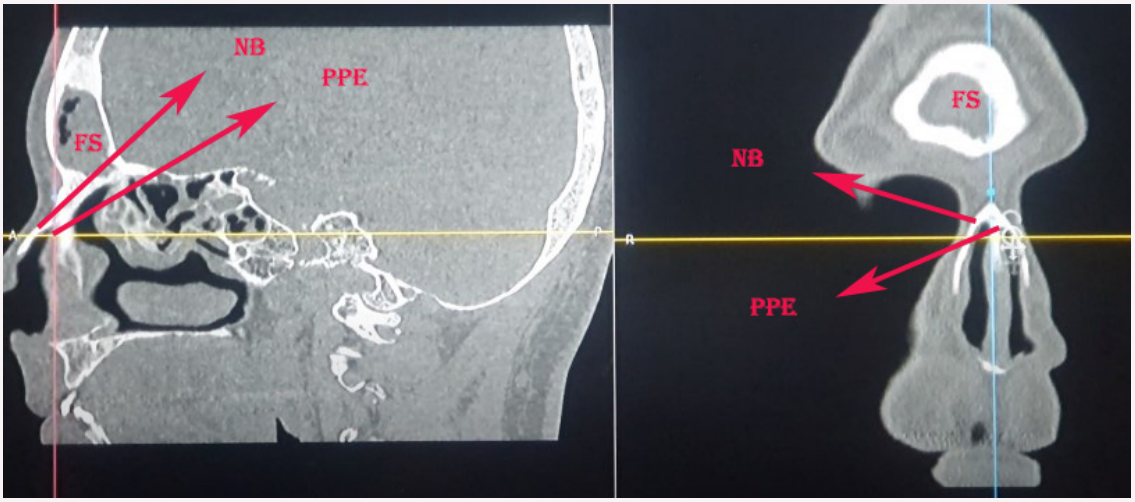


Image showing sagittal and coronal cuts taken at the level of perpendicular plate of ethmoid.
Structures seen include:
NB - Nasal bone
PPE - Perpendicular plate of ethmoid
FS - Frontal sinus
Note - Frontal sinus is filled with fluid secretions

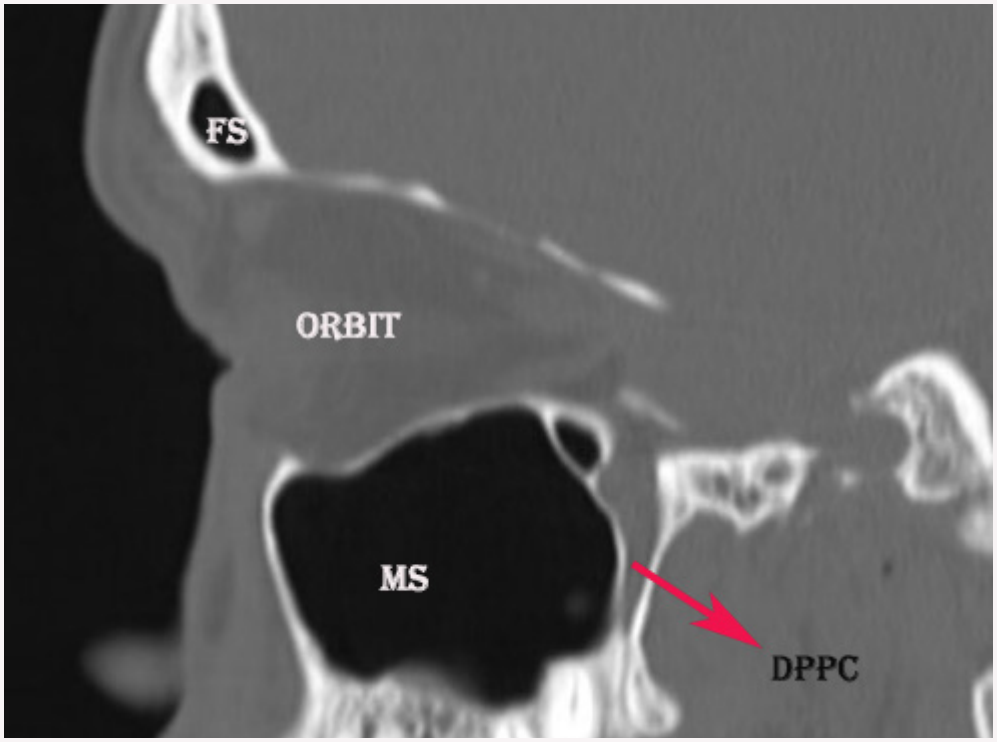


Image showing sagittal CT nose and sinuses showing:
FS - Frontal sinus
MS - Maxillary sinus
DPPC - Descending pterygopalatine canal

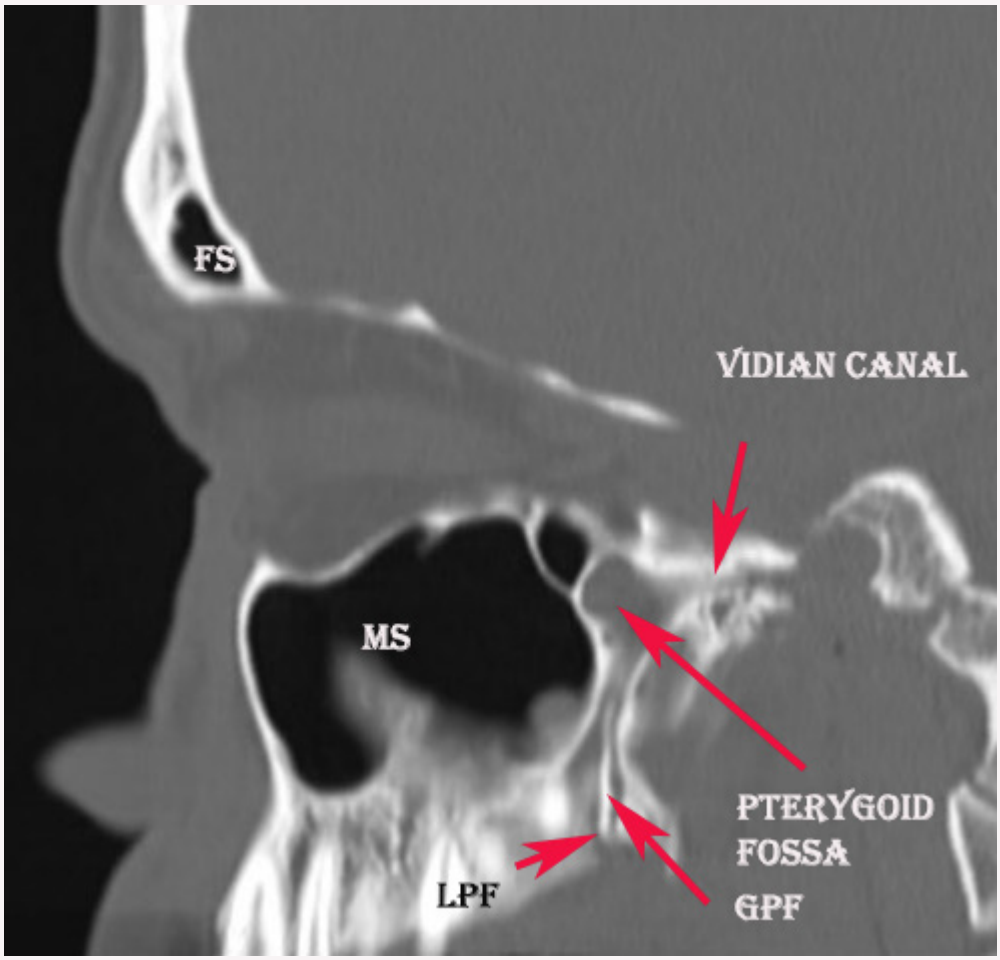


Image showing sagittal view of Nose and sinuses. This view shows structures behind the maxillary sinus.

FS - Frontal sinus
MS - Maxillary sinus
LPF - Lesser palatine foramen
GPF - Greater palatine foramen

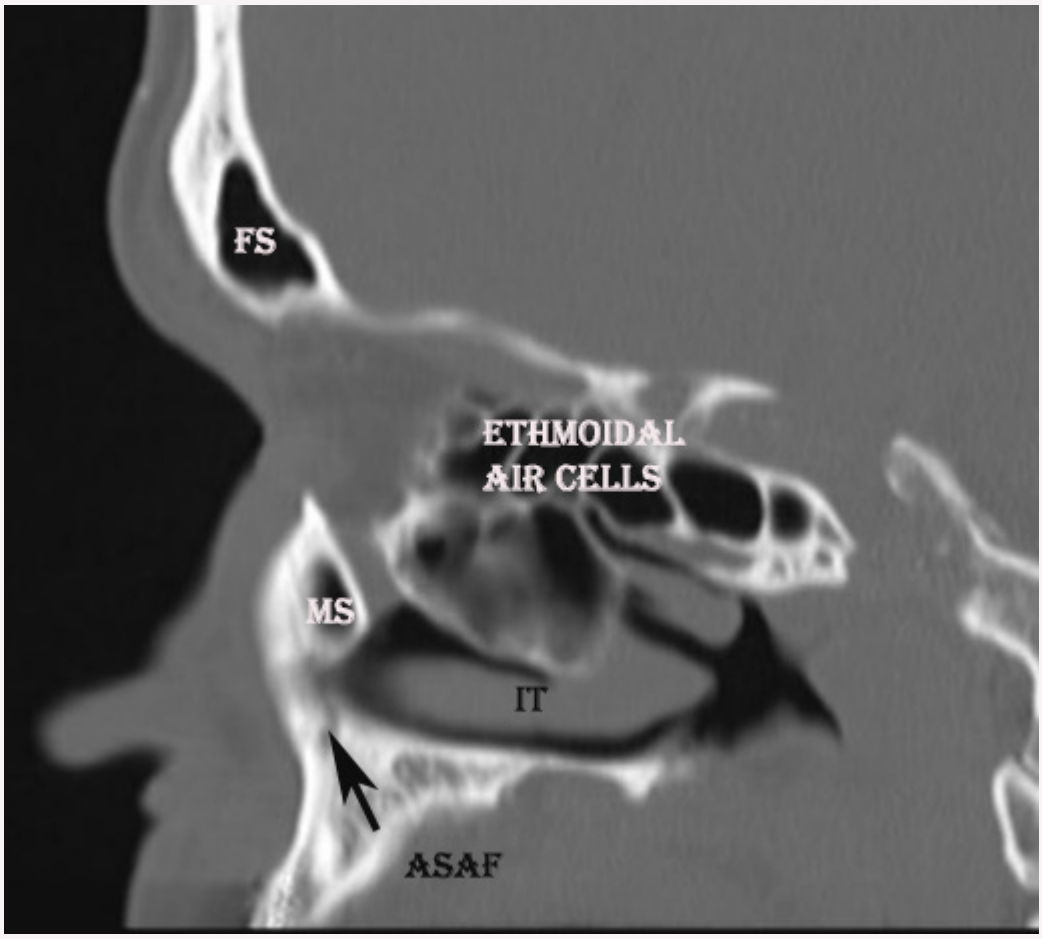


Image showing sagittal section of CT nose and sinuses showing:

FS - Frontal sinus

MS - Maxillary sinus

ASAF - Anterior superior alveolar foramen

IT - Inferior turbinate

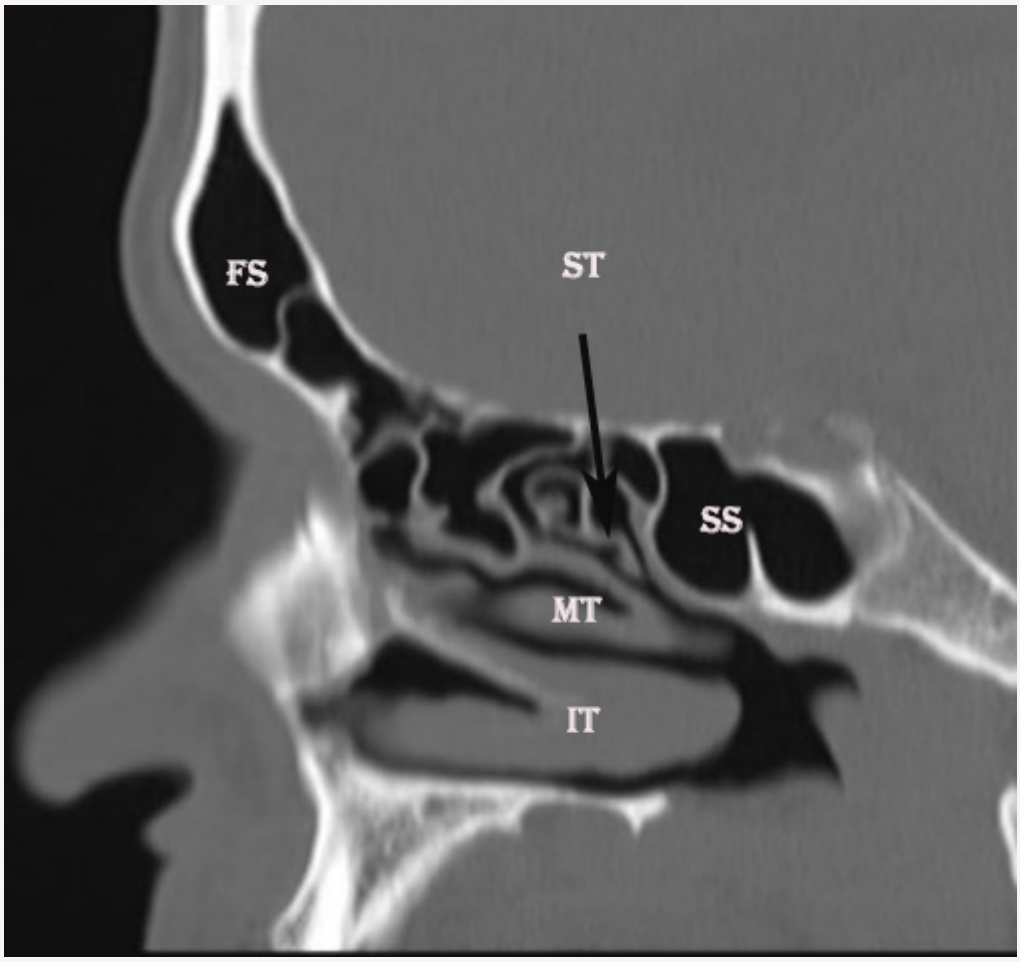


Image showing sagittal CT of nose and sinuses showing:

FS - Frontal sinus

ST - Superior turbinate

MT - Middle turbinate

IT - Inferior turbinate

SS - Sphenoid sinus

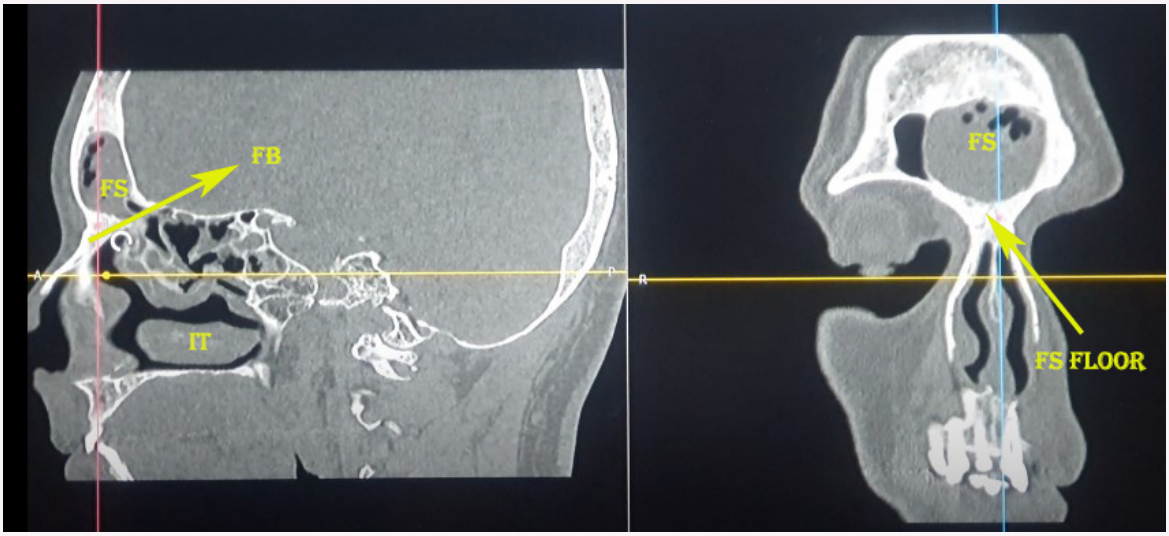


Image showing sagittal and coronal CT cuts of nose and sinuses showing frontal sinus floor.

FS - Frontal sinus

FB - Frontal beak

IT - Inferior turbinate

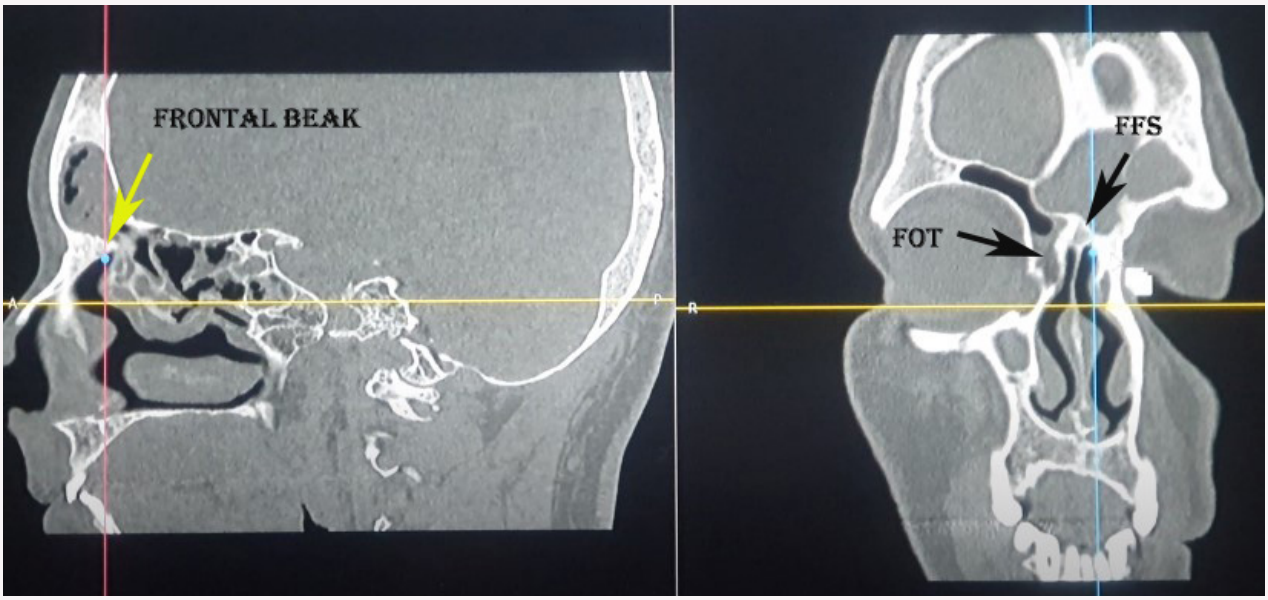


Image showing sagittal and coronal section taken at the level of frontal beak.

FOT - Frontal outflow tract

FFS - Floor of frontal sinus

Vital difference between frontal outflow tract and frontal sinus is the presence of bridge of bone between medial orbital wall and the perpendicular plate of ethmoid bone. This is clearly evident in the image above where this bridge of bone is absent on the right side indicating the presence of frontal outflow tract. On the left side this bridge of bone is present indicating the floor of the frontal sinus is still visible on the left side in this cut.

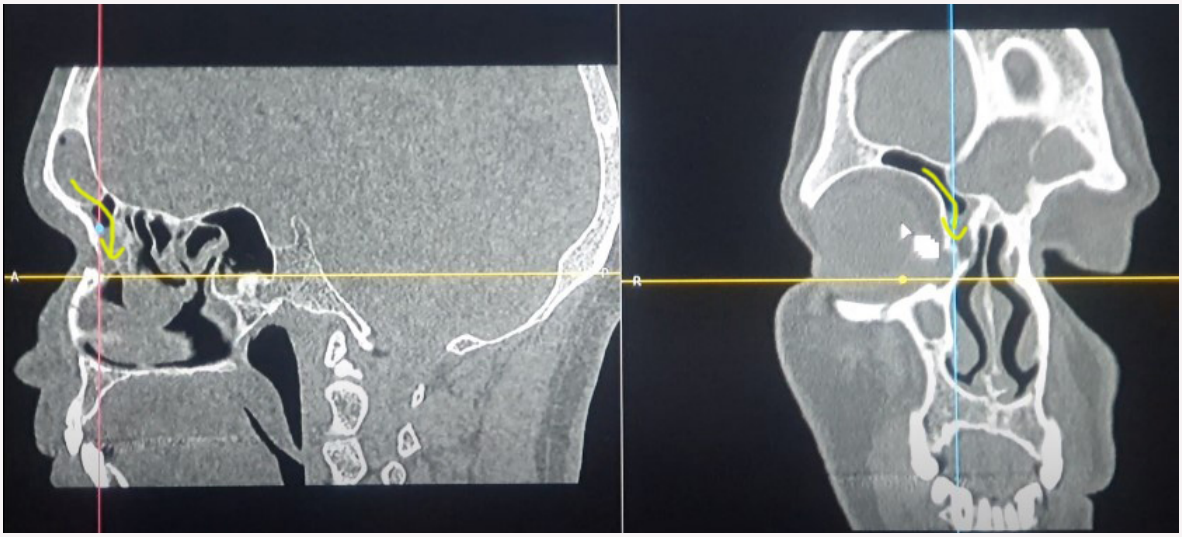


Image showing both sagittal and coronal sections of CT nose and sinuses. The cut is focussed on the frontal outflow tract (right side). It is indicated by yellow arrow. Note the presence of floor of the frontal sinus on the left side in coronal section. Frontal lobe of the brain is visible behind the frontal sinus outflow tract in the sagittal veiw. In the coronal view frontal lobe is seen above the frontal outflow tract. Since frontal sinus outflow tract is present at varying levels on the right and left side, this image shows outflow tract on one side and floor of the frontal sinus on the other. Preoperative understanding of this asymmetry will help the surgeon to identify the frontal sinus outflow tract from the frontal sinus perse as surgery is performed only in the frontal sinus outflow tract and not on the frontal sinus. The entire anatomy of the frontal sinus outflow tract will be clearly visible in sagittal section. Anterior and posterior relations of this tract can also be clearly seen in sagittal cuts.

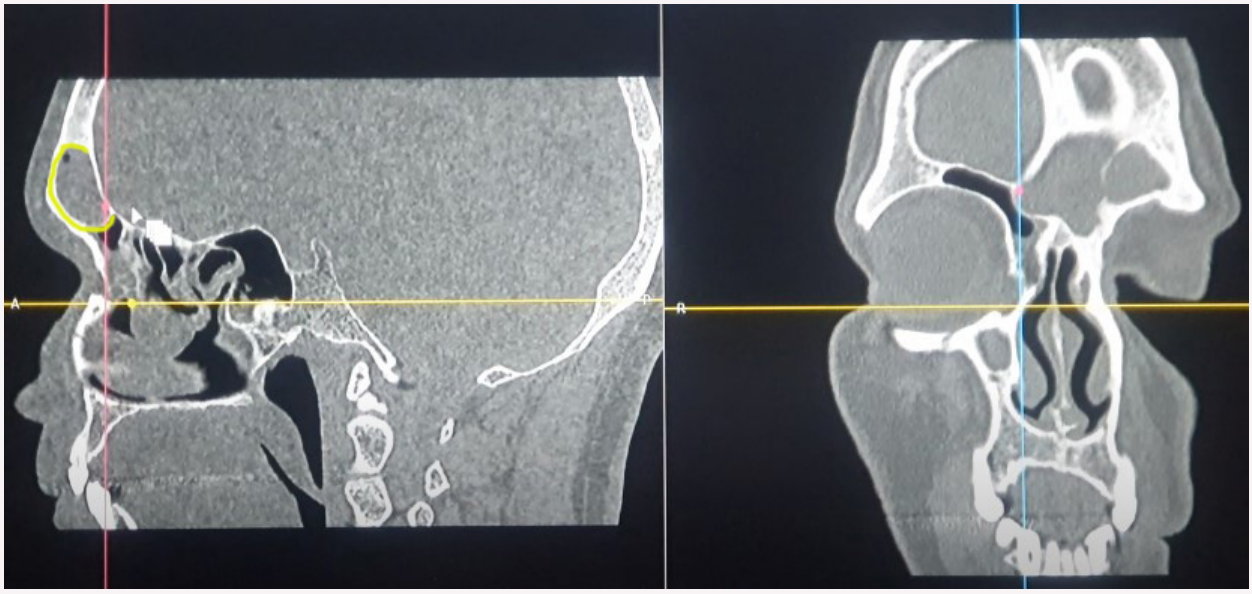


Image showing a seperate air cell within the frontal sinus in the sagittal cut. This air cell has a superior border, anterior border and inferior border. (Yellow). Posterior wall of the air cell is not visible. This air cell on first look appears to be Khun type 4 cell. But it is actually an frontal intersinus cell.

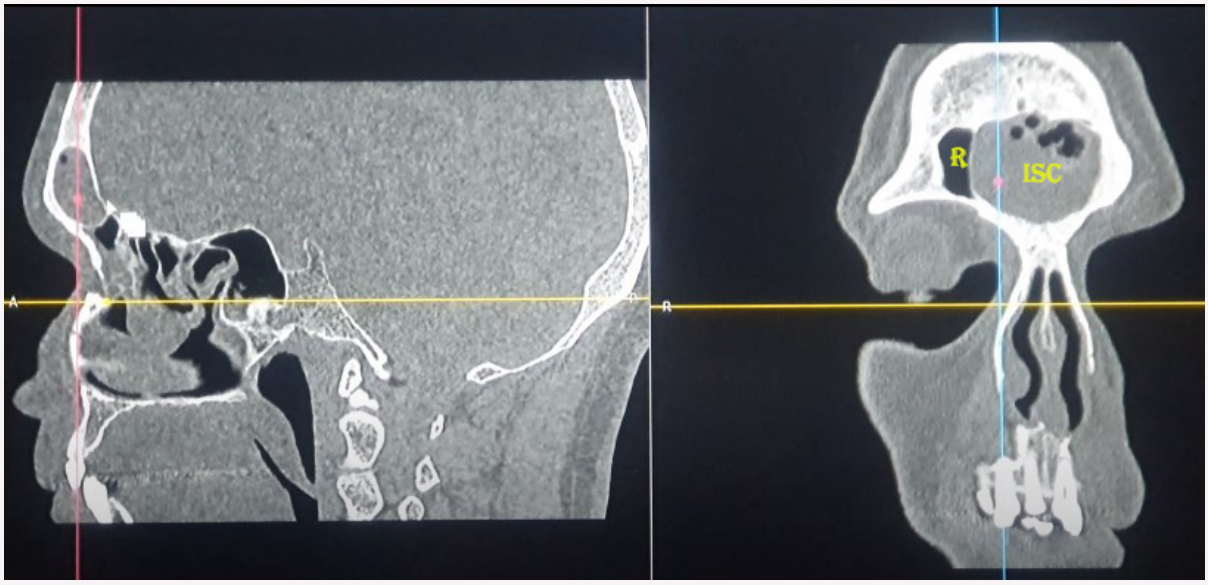


Image showing sagittal and coronal sections of CT nose and sinuses.

R - Right frontal sinus

ISC - Intersinus cell. This cell is so large that it has managed to push the left frontal sinus laterally. This will be clearly seen in the next cut shown below.

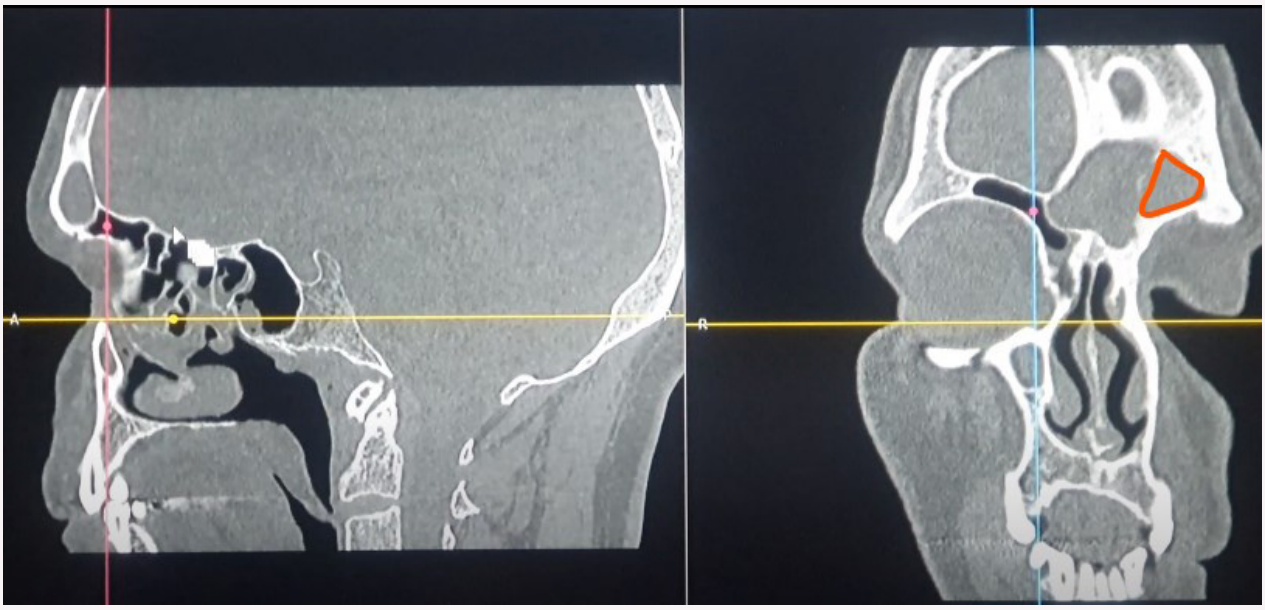


Image showing sagittal and coronal sections of CT nose and sinuses. Interfrontal sinus cell is clearly shown in the coronal section pushing the left frontal sinus further laterally (Orange color).

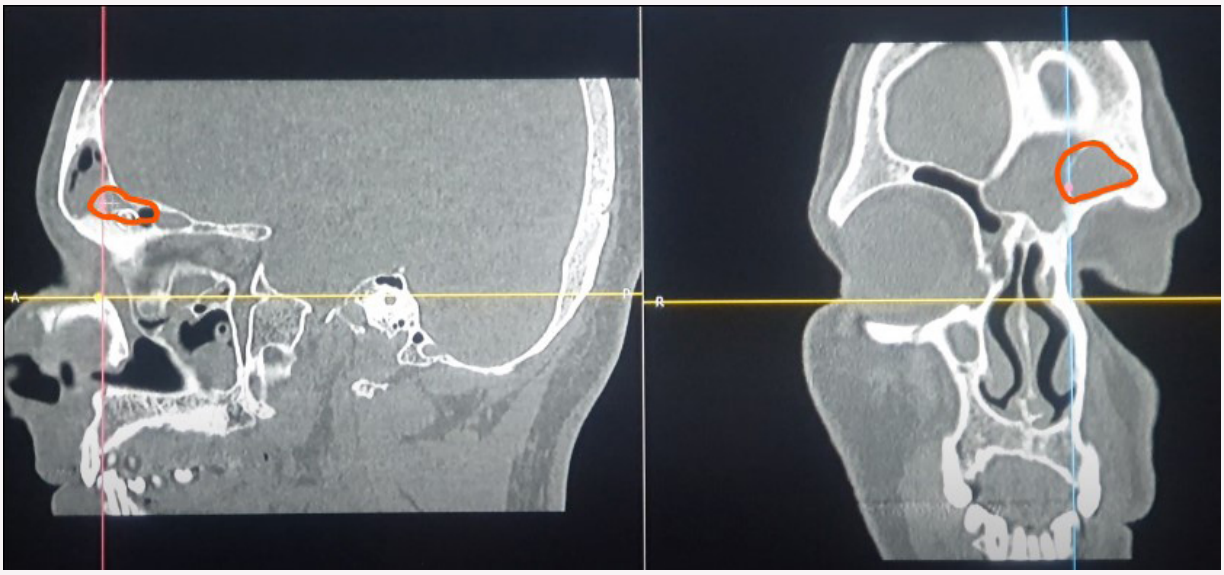


Image showing sagittal and coronal sections CT nose and sinuses showing interfrontal cell pushing the left frontal sinus laterally (orange) in both these sections it is seen.

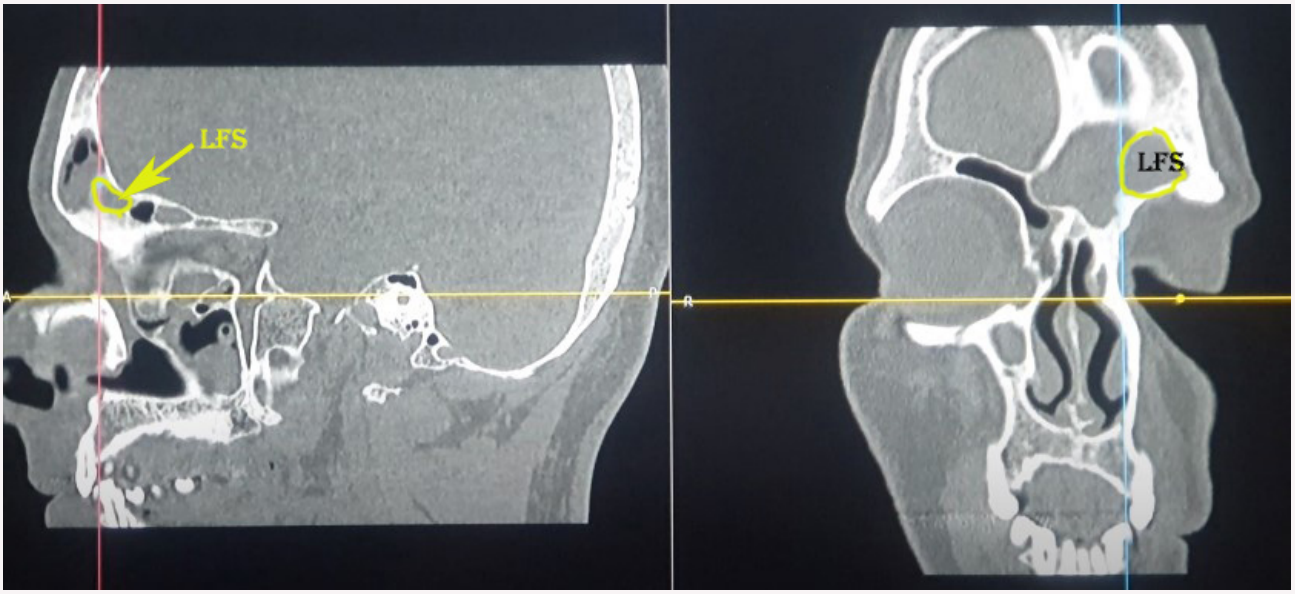


Image showing laterally pushed left frontal sinus by the inter frontal cell. Marked in yellow in both cuts. It can be better appreciated in coronal section. This large interseptal cell is opening into the left frontal recess area.

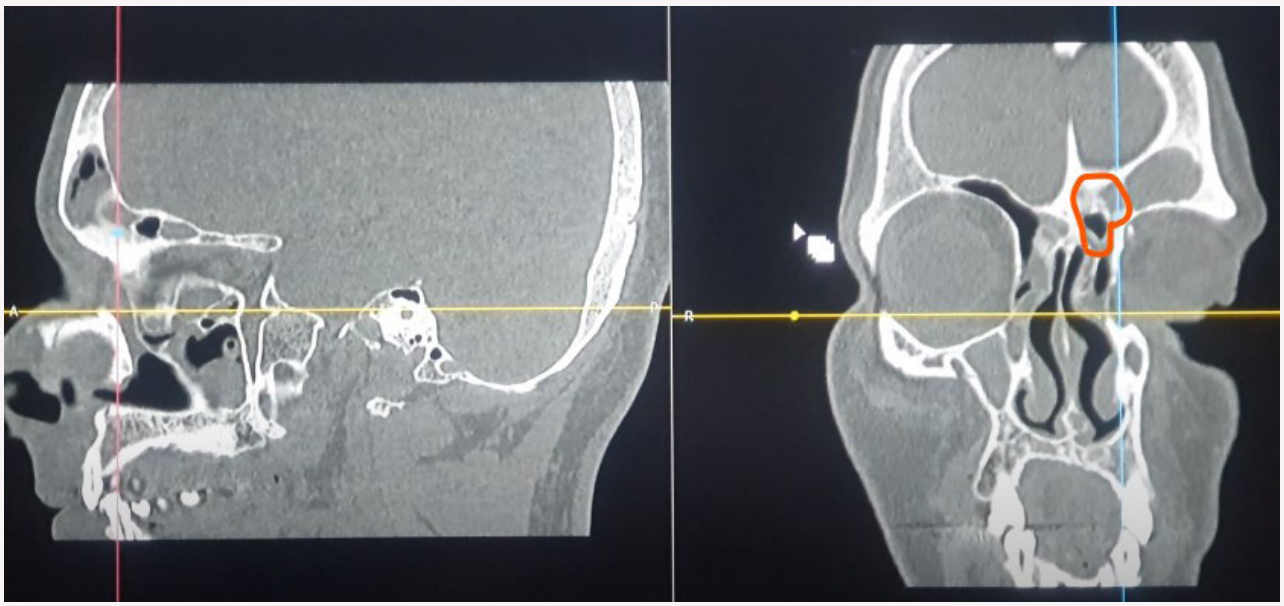


Image showing large interfrontal cell pushing the left frontal sinus laterally. Note the interfrontal cell is draining into the left frontal recess area.

Type IV Khun cell if present will not have an attachment to the posterior table of the frontal sinus. On the other hand interfrontal cell would have an attachment to the posterior table of the frontal sinus.

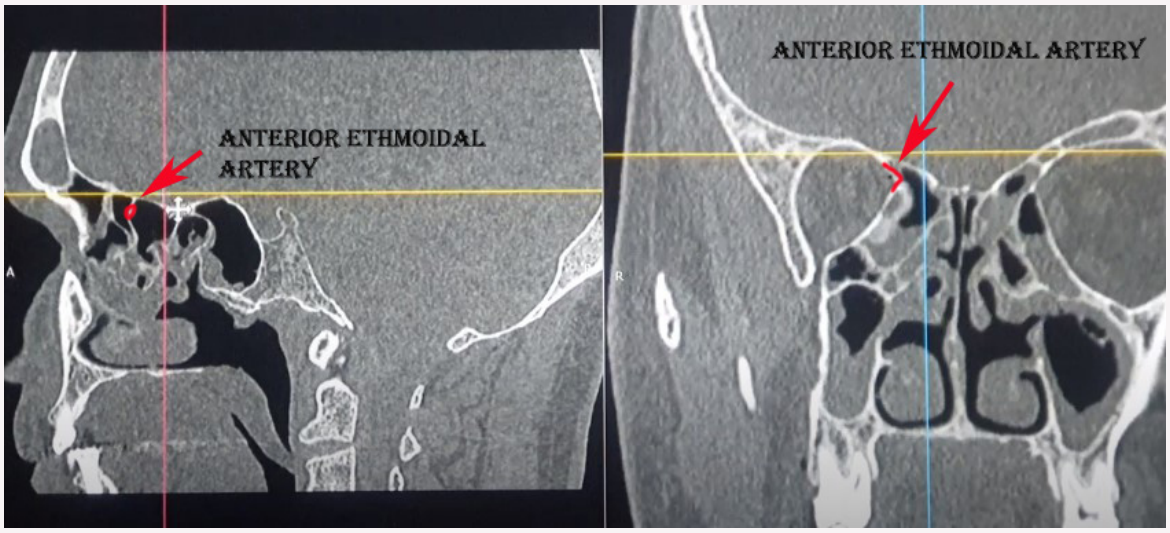


Image showing anterior ethmoidal artery in both sagittal and coronal sections. This location is marked in the coronal section by the presence of Kennedy's nipple. This is present at the junction of the superior oblique and medial rectus. The anterior ethmoidal artery lies just a few millimeters below anterior skull base. If the surgeon encounters anterior ethmoidal artery during surgery then it should be construed that the skull base lies just a few milllimeters above it. Anatomically anterior ethmoidal artery lies few millimeters in front of ground lamella (basal lamella).

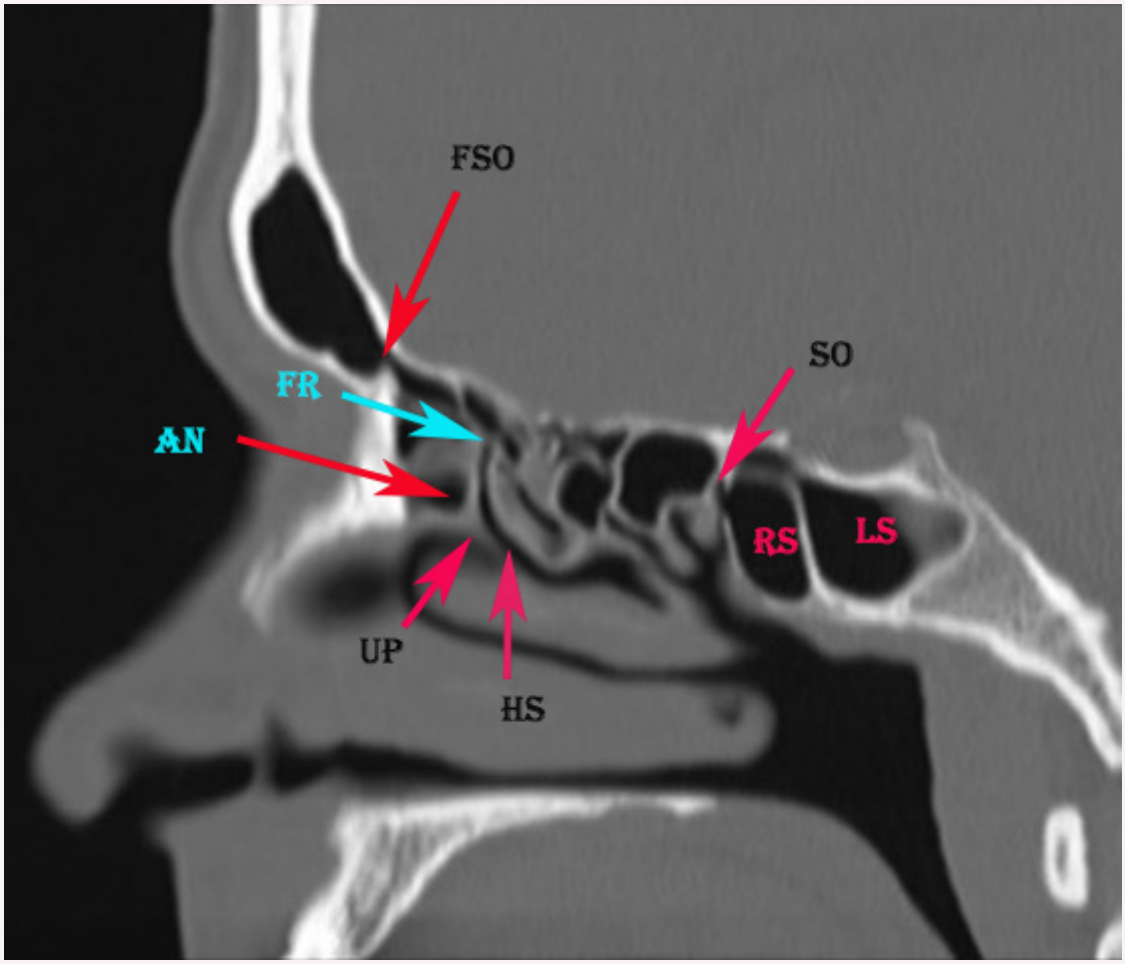


Image showing sagittal cut of CT nose and sinuses showing:

FSO - Frontal sinus outflow tract

FR - Frontal recess

AN - Agger nasi

UP - Uncinate process

HS - Hiatus semilunaris

SO - sphenoid ostium

RS - Right sphenoid

LS - Left sphenoid

Note - Right sphenoid sinus lie in front of left sphenoid sinus in the sagittal cut

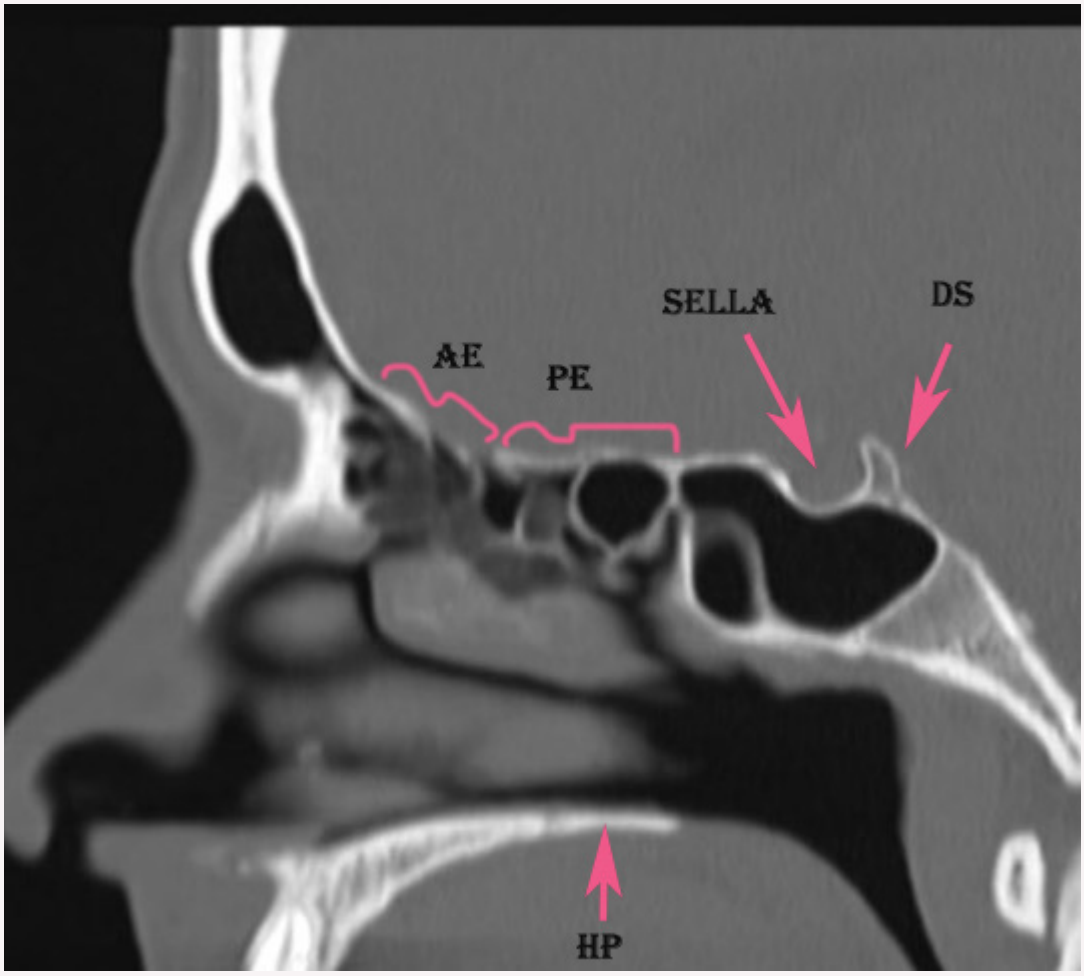


Image showing sagittal CT of nose and sinuses showing:

AE - Anterior ethmoid air cells

PE - Posterior ethmoid air cells

DS - Dorsum sella

HP - Hard palate

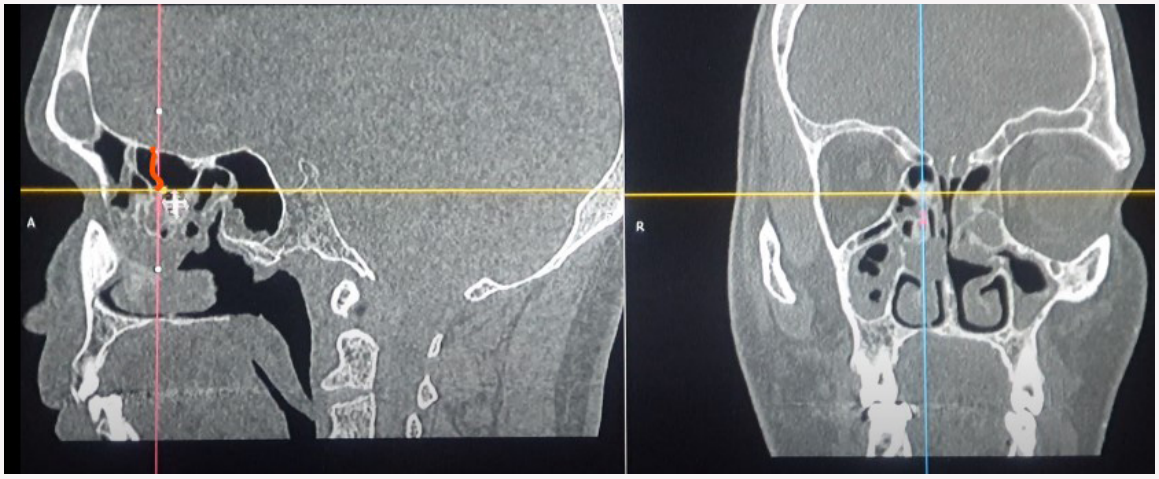


Image showing sagittal and coronal sections of CT nese and sinuses. Orange line indicates the level of the basal lamella. Air cells anterior to this line belong to the anterior ethmoidal group and air cells behind this line belong to the posterior ethmoid group.

For the sake of easy understanding the middle turbinate is divided into three portions:

Anterior third - This portion of the middle turbinate is attached to the skull base and it lies in the sagittal plane.

Middle third - This portion of the middle turbiante is oriented in the coronal plane and is attached to lamina papyracea.

Posterior third - This portion of the middle turbinate is oriented in axial plane and is attached to the perpendicular plate of palatine bone close to the roof of choana.

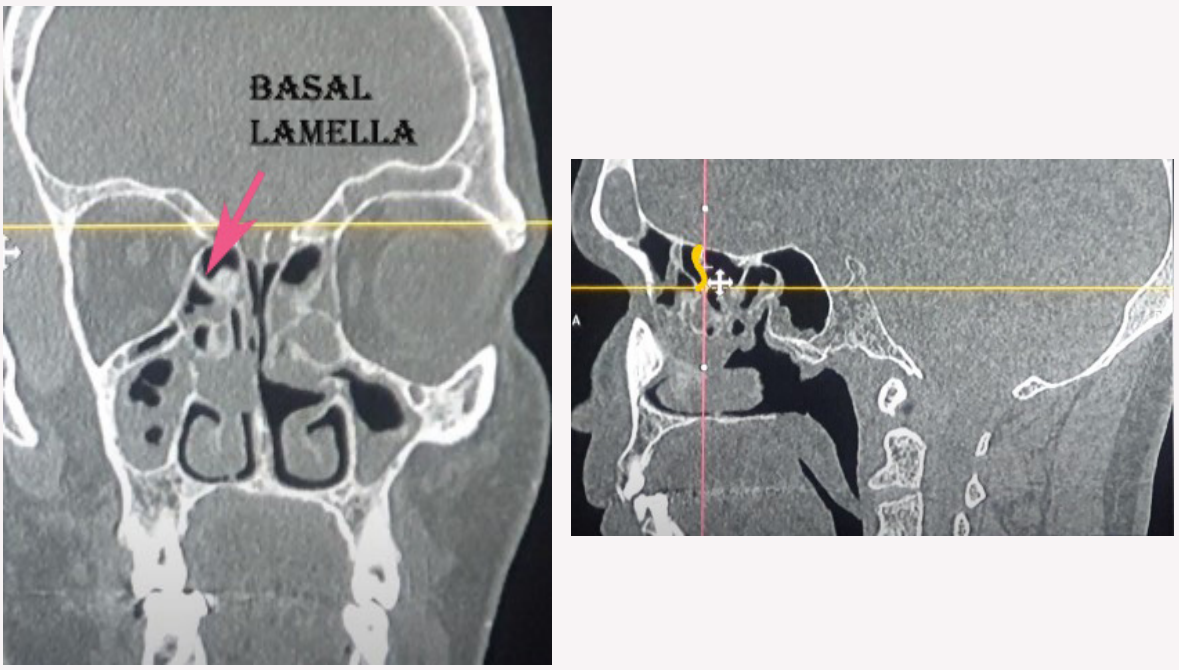


Image showing coronal and sagittal sections of CT nose and sinuses showing Basal lamella. In the sagittal section basal lamella is indicated by yellow line. In the sagittal section the anterior ethmoidal cells in front of basal lamella and posterior ethmoidal cells behind the basal lamella can be clearly seen. The skull base above the posterior ethmoidal air cells tend to be thicker and flat when compared to that of anterior skull base which is thinner and more oblique.

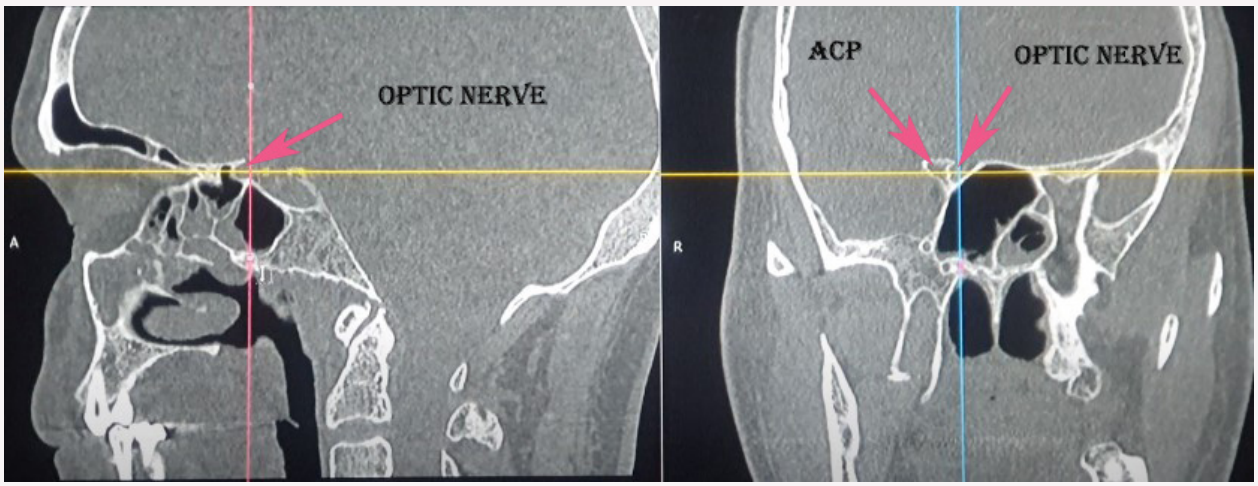


Image showing sagittal and coronal CT of nose and sinuses showing optic nerve.

ACP - Anterior clinoid process

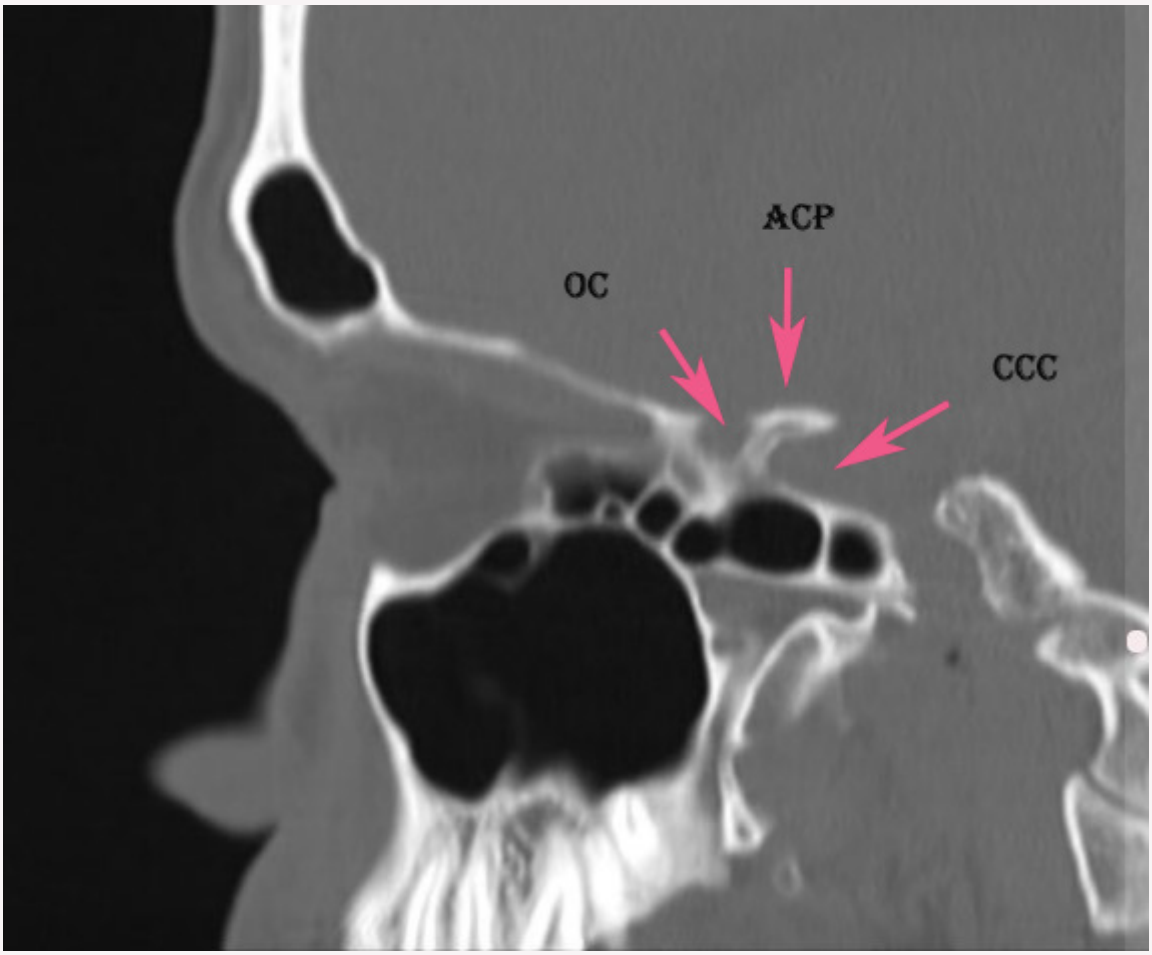


Image showing sagittal CT nose and sinuses showing:

OC - Optic canal

ACP - Anterior clinoid process

CCC - Clinocarotid canal

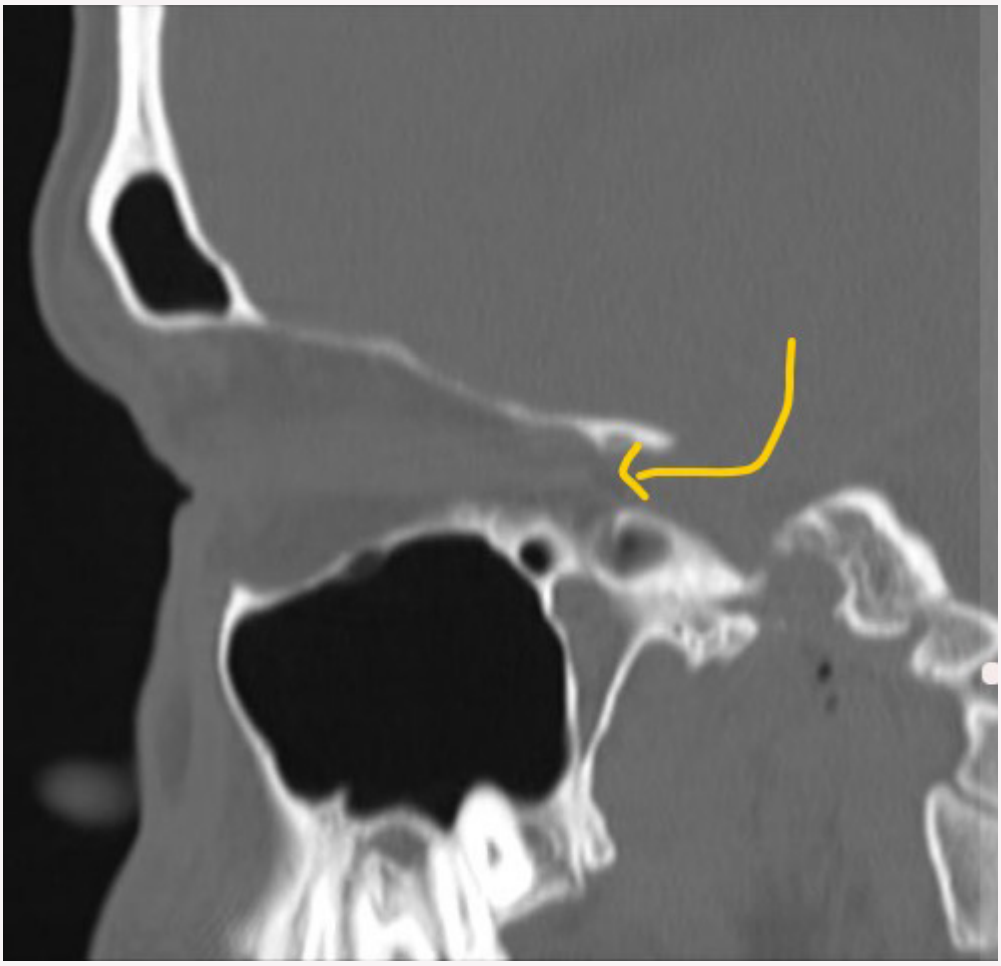


Image showing sagittal CT of nose and sinuses showing superior orbital fissure (yellow arrow).

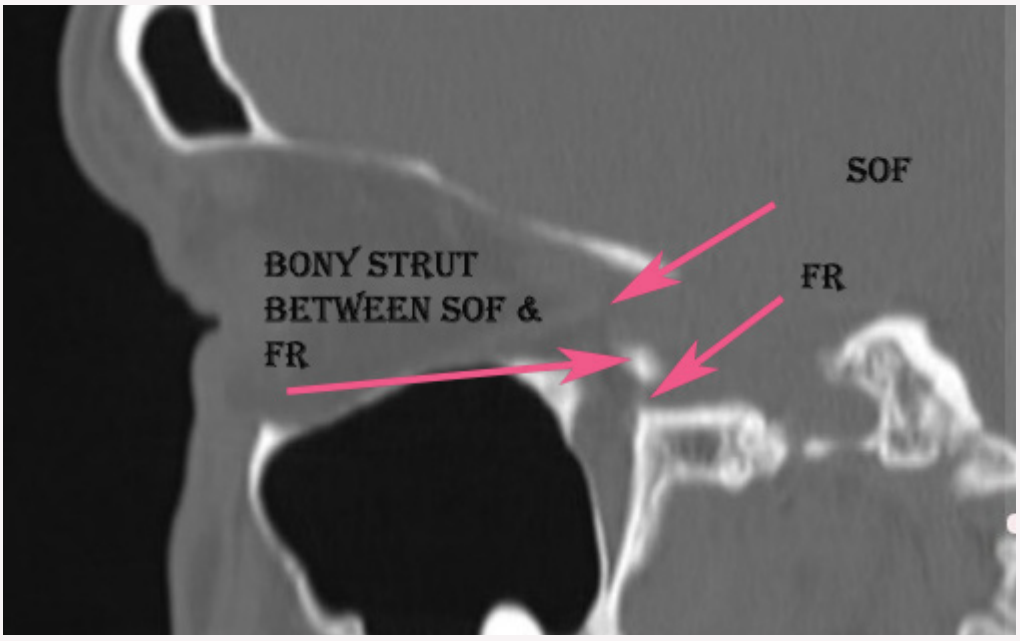


Image showing sagittal CT of nose and sinuses showing:
SOF - Superior orbital fissure
FR- Foramen rotundum

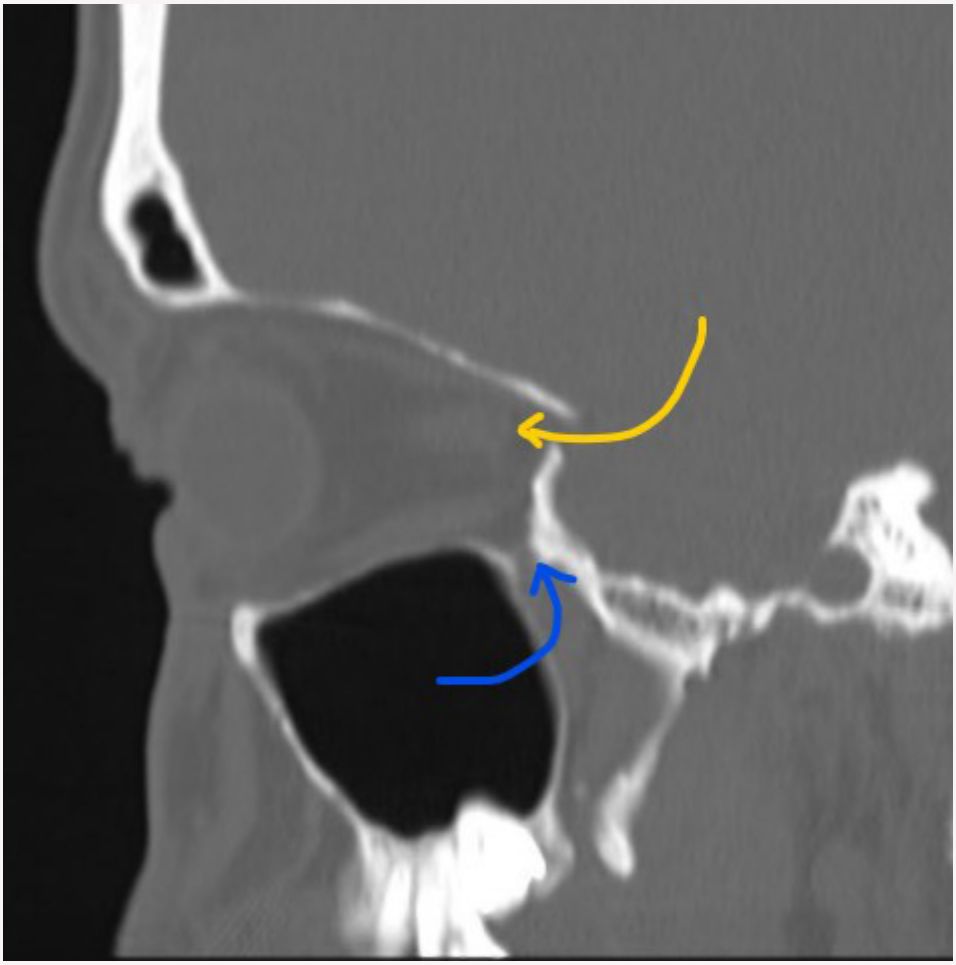


Image showing sagittal CT of nose and sinuses showing:

Superior orbital fissure (yellow arrow)

Inferior orbital fissure (Blue arrow)

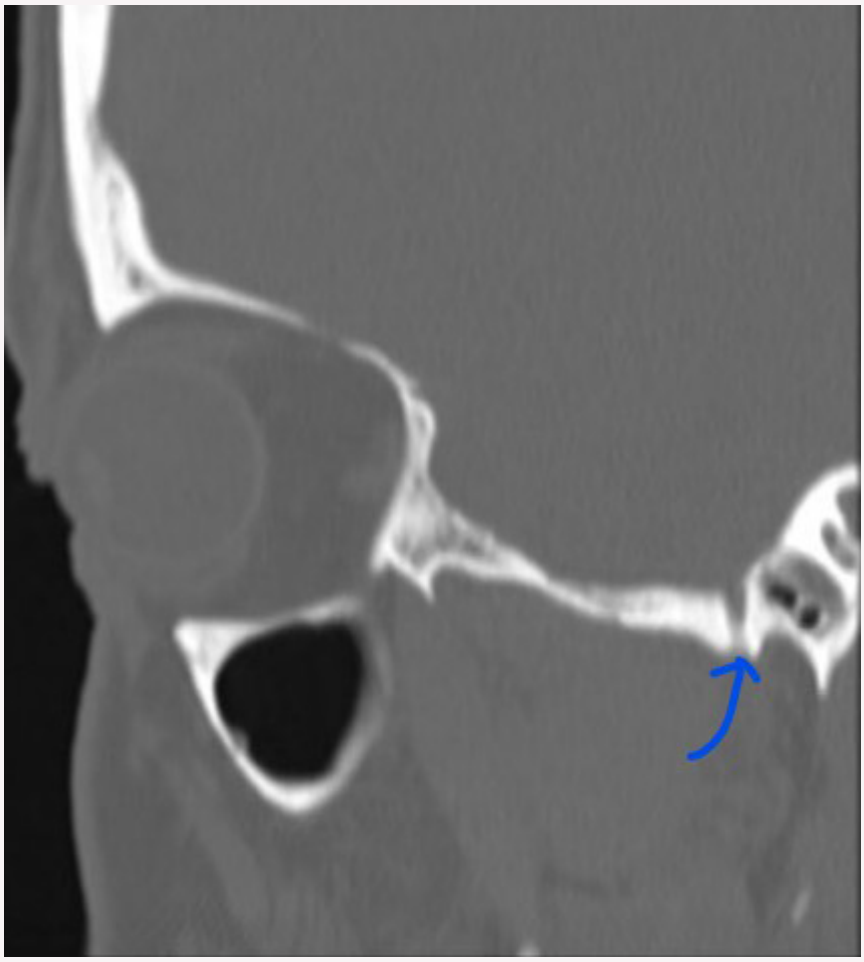


Image showing sagittal CT of nose and sinuses showing foramen spinosum (Blue arrow)

[1]

Anatomical variations of paranasal sinuses

Intranasal anatomy is highly variable. Surgeon embarking on endoscopic sinus surgery should be aware of these critical anatomical variations lest he / she is liable to cause iatrogenic complications during the surgical procedure. This is where Pre operative CT imaging of nose and sinuses come into play. Coronal CT of nose and sinuses reveals intranasal anatomy as seen by the surgeon during surgery.

Ethmoidal air cell system is the most complex and highly variable of all the intranasal structures. it should also be stressed that these air cell system lie in close proximity to vital structures like orbit and skull base. Anterior skull base is paper thin in some places and in the anterior skull base it slopes downwards. Surgeon can inadvertantly breach this barrier causing CSF leak following endoscopic sinus surgery. Some of the anatomical variations can predispose to obstruction to paranasal sinus drainage pathways leading on to sinusitis. In this chapter various common anatomical variations that can be gleaned from CT images will be elaborated. This by no means should be considered as the full list of anatomical variations, only the common and significant ones will be listed here.

Deviated nasal septum:

Septal deviations are pretty common occurrence. Infact a dot central nasal septum is a clinical curiosity. Eventhough septal deviations are common they are usually not severe enough to cause symptoms.

Deviated nasal septum can be caused by:

Direct trauma - Many septal deviations are a result of direct trauma and this is frequently associated with damage to other parts of the nose such as fractures of nasal bone.

Birth moulding theory - Many patients with septal deviation do not give history of trauma. Birth moulding theory was propounded by Gray. According to him abonromal intrauterine posture may result in compression forces acting on the nose and upper jaws. Displacement of septum can occur in these patients due to torsion forces that occur during parturition. Dislocations are more common in primipara and when the second stage of labour lasted for more than 15 minutes. Dislocations are generally to the right in the case of left occipitoanterior presentations and to the left with right occipitoanterior presentations. Subsequent growth of nose accentuates these asymmetries.

Differential growth between nasal septum and palate - This is the most acceptable theory today. When the nasal septum grows faster in certain individuals than the palate then the nasal septum starts to buckle under pressure.

Deformity of nasal septum may be classified into:

1. Spurs

2. Deviations

3. Dislocations

Spurs - These are sharp angulations seen in the nasal septum occuring at the junction of the vomer below, with the septal cartilage and / or ethmoid bone above. This type of deformity is the result of vertical compression forces. Fractures that occur through nasal septum during injury to the nose may also produce sharp angulations . These fractures heal by fibrosis that extend to the adjacent mucoperichondrium. This increases the difficulty of flap elevation in this area.

Deviations - May be C shaped or S shaped. These can occur in either vertical or horizontal plane. It may also involve both cartilage and bone.

Dislocations - In this the lower border of the septal cartilageis displaced from its medial position and projects into one of the nostrils.

In patients with septal deviation a compensatory hypertrophy of the turbinates and bulla may occur on the side opposite to the deviation. If compression forces are involved the septal deviations are often asymmetrical and may also involve the maxilla, producing flattenting of the cheek, elevation of the floor of the affected nasal cavity, distortion of the palate and associated orthodontic abnormalities. The maxillary sinus is usually slightly smaller on the affected side.

Anterior septal deviations are often associated with deviations in the external nasal pyramid. Deviations may affect any of the three vertical components of the nose causing:

1. Cartilagenous deviations

2. The C deviation

3. The S deviation.

Cartilagenous deviations:

In these patients the upper bony septum and the bony pyramid are central, but there is a dislocation / deviation of the cartilagenous septum and vault.

The C deviation:

Here there is displacement of the upper bony septum and the pyramid to one side and the whole of the cartilagenous septum and vault to the opposite side.

The S deviation:

Here the deviation of the middle third (the upper cartilagenous vault and associated septum) is opposite to that of the upper and lower thirds. With deviations of the nose, the dominant factor

is the position of the nasal septum, hence the adage 'as the septum goes, so goes the nose'. The first step, therefore in treating the twisted nose is to straighten the septum, and if this objective is not achieved, there is no hope of successfully straightening the external pyramid.

Effects of septal deviation:

Nasal obstruction - This is always found on the side of the deviation, and can also be present on the opposite side as a result of hypertrophic changes of the turbinates.

Mucosal changes - The inspiratory air currents are abnormally displaced and frequently gets concentrated on small areas of nasal mucosa, producing excessive drying effect. Crusting will occur and the separation of the crusts often produces ulceration and bleeding. Since the protective mucous layer is lost the resistance to infection is reduced. The mucosa around a septal deviation may become oedematous as a result of Bernouilli's phenomenon. This oedema further increases nasal obstruction.

Neurological changes - Pressure may be exerted by septal deviations on adjacent sensory nerves can produce pain. This was first explained by Sluder and the resultant condition became known as the anterior ethmoidal nerve syndrome'. In addition to these direct neurological effects, reflex changes perhaps may result from septal deformities which affect the nasopulmonary and nasal reflexes.

Septal deviations have direct correlation with the roominess of nasal cavity. This aspect should be viewed carefully by the surgeon who is planning endoscopic sinus surgery since there should be adequate space for passing the passage of endoscope and surgical instruments during the procedure. Pre operative CT images could reveal the extent of the deviation to the surgeon so that if need be septoplasty canbe planned prior to the actual endoscopic surgical procedure.

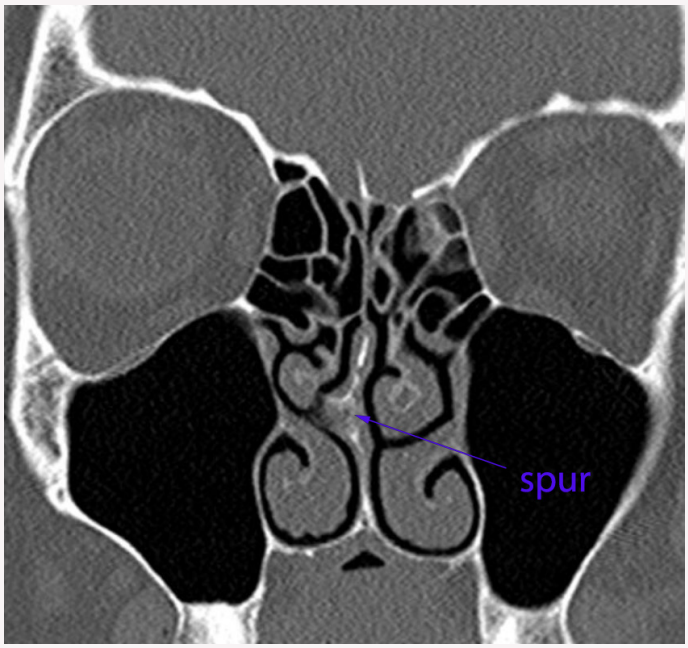


Image showing coronal CT of nose and sinuses revealing the presence of septal spur probably caused by injury to the nose

Coronal sections will clearly reveal the presence of septal deviation / spur. The extent of the deviation may not be evident from a single cut. To glean this information multiple sequential coronal cuts need to be studied. If 5 mm / 7 mm cuts are taken then a small septal spur would be lost in the sequence of images. It is precisely for this reason thin sections are advisable 2 mm cuts or less.

Image showing axial CT of nose and sinuses. In this cut the entire extent of the deviation of nasal septum is clearly visible. Also note the mucosal contact point between nasal septal mucosa and the inferior turbinate mucosa.

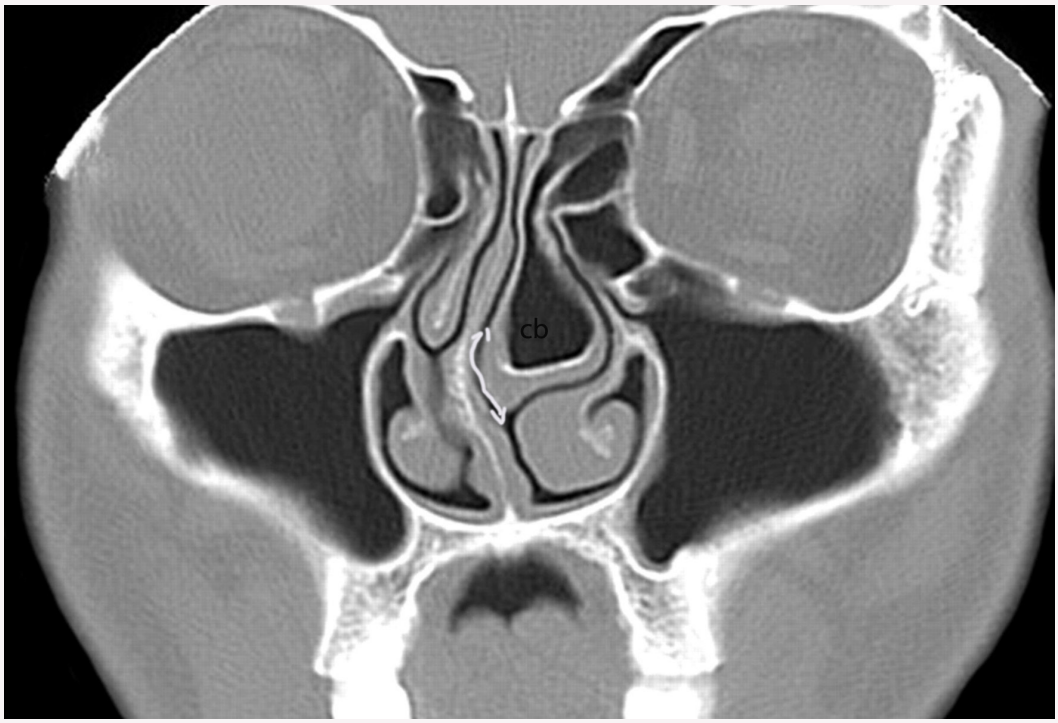


Image showing coronal section of CT nose and sinuses showing deviated nasal septum to the right with a roomy nasal cavity on the left side. Note the roomy left nasal cavity is occupied by concha bullosa of middle turbinate. Note air passage between concha bullosa and nasal septum. This is invariably present in all such cases.

This implies that the deviation of the septum away from the concha is not the result of the concha pushing the septum. Rather, there appears to be some as yet unknown developmental relationship between a concha and the nasal septum. Commonly the roomy nasal cavity caused by deviated nasal septum is occupied by enlarged inferior turbinate or concha bullosa of the middle turbinate.

Image showing axial CT of nose and sinuses showing deviated nasal septum to left side and presence of concha bullosa on the right side

High septal deviations can cause narrowing at the level of middle meatus impeding drainage from the middle meatus. This will happen if there is contact area between the septal mucosa and the mucosal lining of the middle meatus. Contact areas impede mucociliary clearance mechanism causing bockage to the drainage of anterior group of paranasal sinuses.

Anatomical abonormalities in Middle turbinate:

Concha Bullosa:

Nasal turbinates develop as outgrowths arising from the lateral nasal wall known as ethmoturbinals. The middle turbinate arises from the third ridge. Variations in pneumatization of these ethmoturbinals may lead to anatomical variations within the bony structures of ethmoidal labyrinth.

Bolger1classified pneumatization of middle turbinate into three types:

Lamellar type pneumatization: This involves pneumatization of vertical lamella of middle turbinate.

Bulbous type pneumatization: Involves pneumatization of inferior portion of middle turbinate

Extensive pneumatization: Involves pneumatization of both lamellar portion and inferior portion of middle turbinate. It is also known as Concha bullosa.

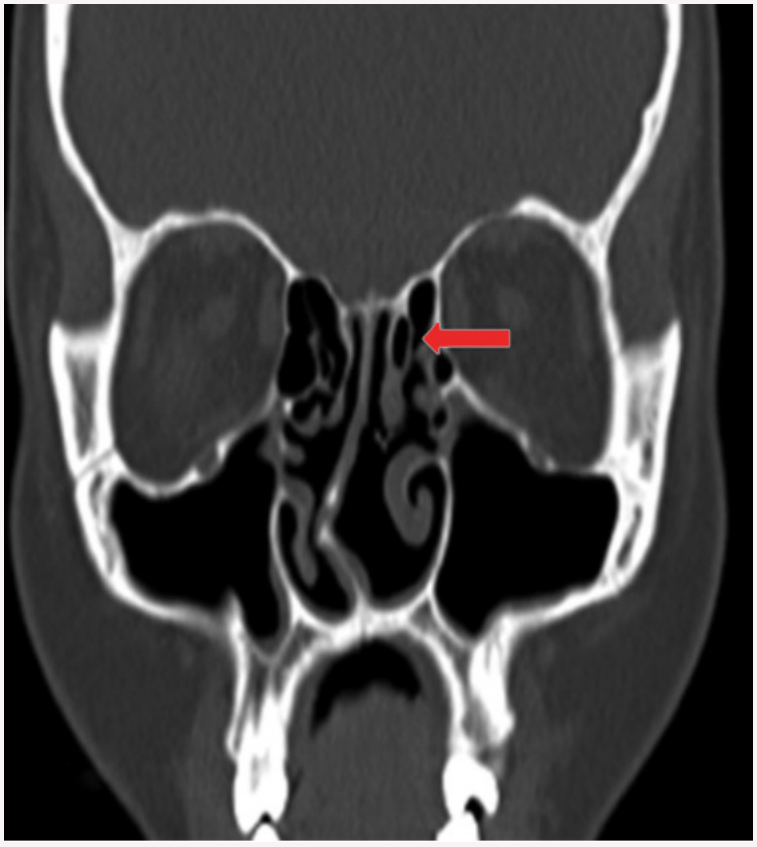


Image showing coronal CT of nose and sinuses showing lamellar concha bullosa (red arrow)

Image showing coronal CT of nose and sinuses showing bulbous concha bullosa on the right side and concha bullosa on tthe left. Presence of a large concha bullosa can cause narrowing of middle meatus impeding drainage from anterior group of sinuses. Presence of a large concha of middle turbinate can predispose to sinus infections

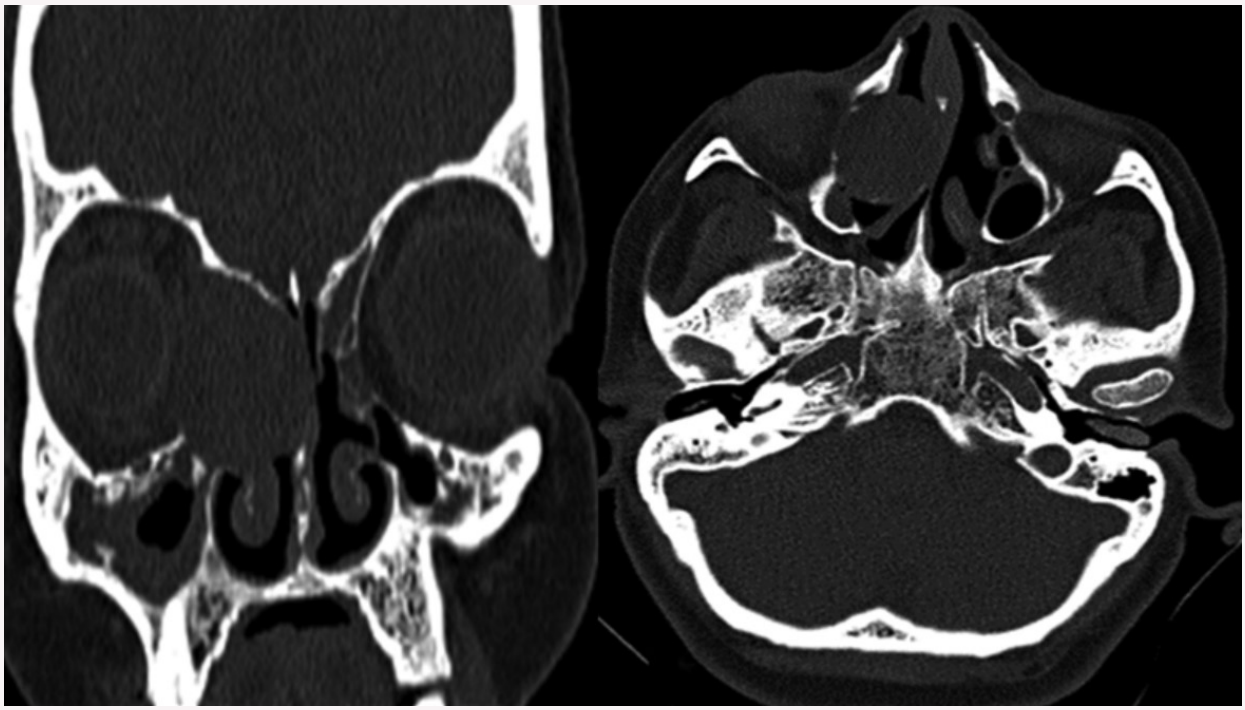


Image showing coronal and axial CT of nose and sinuses showing opacity in the concha bullosa probably caused by accumulation of pus within it. Suggestive of pyocele of concha bullosa.

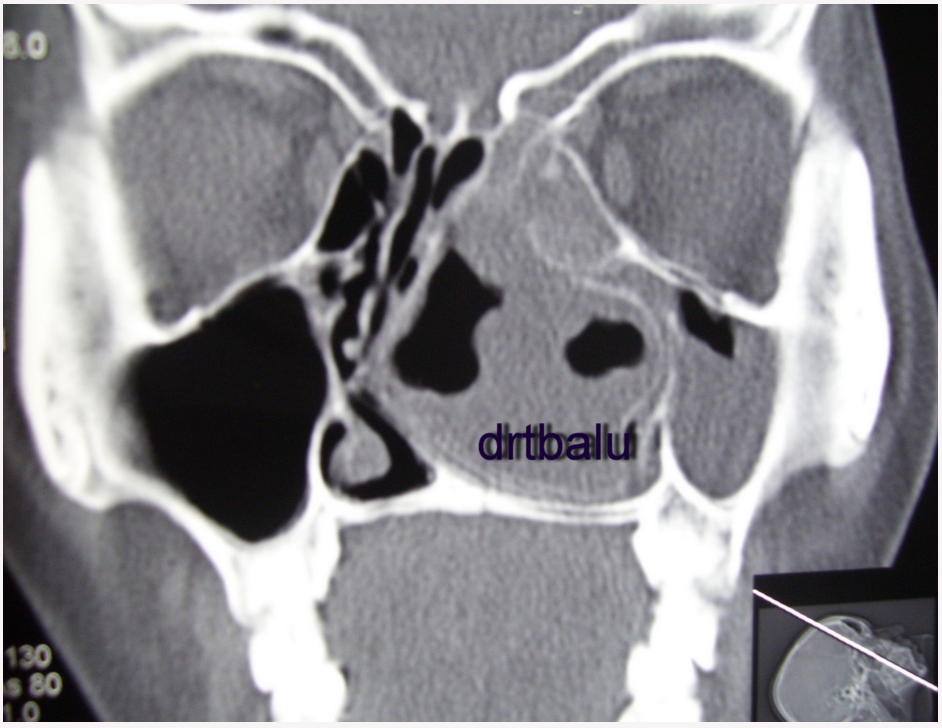


Image showing a huge infected concha bullosa on the left side. Size of the maxillary sinus is also reduced on the left side due to the presence of a large concha.

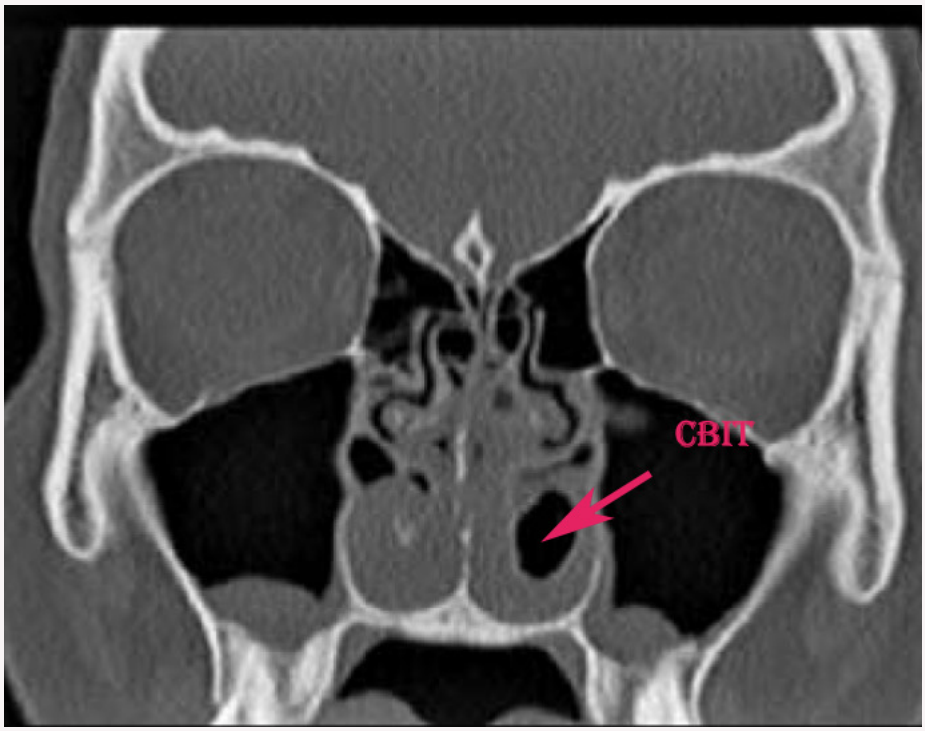


Image showing coronal CT of nose and sinuses with:
CBIT - concha bullosa inferior turbinate. This indicates pneumatization of inferior turbinate.

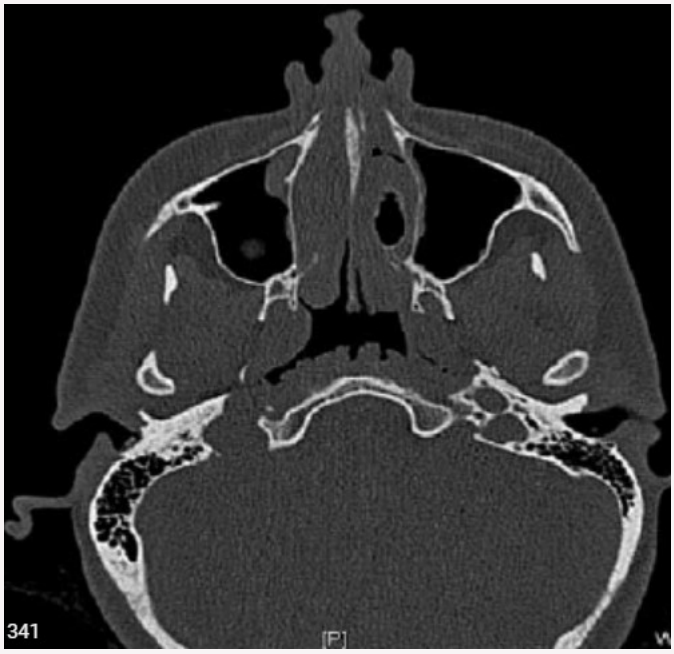


Image showing axial scan of nose and sinuses showing concha bullosa inferior turbinate

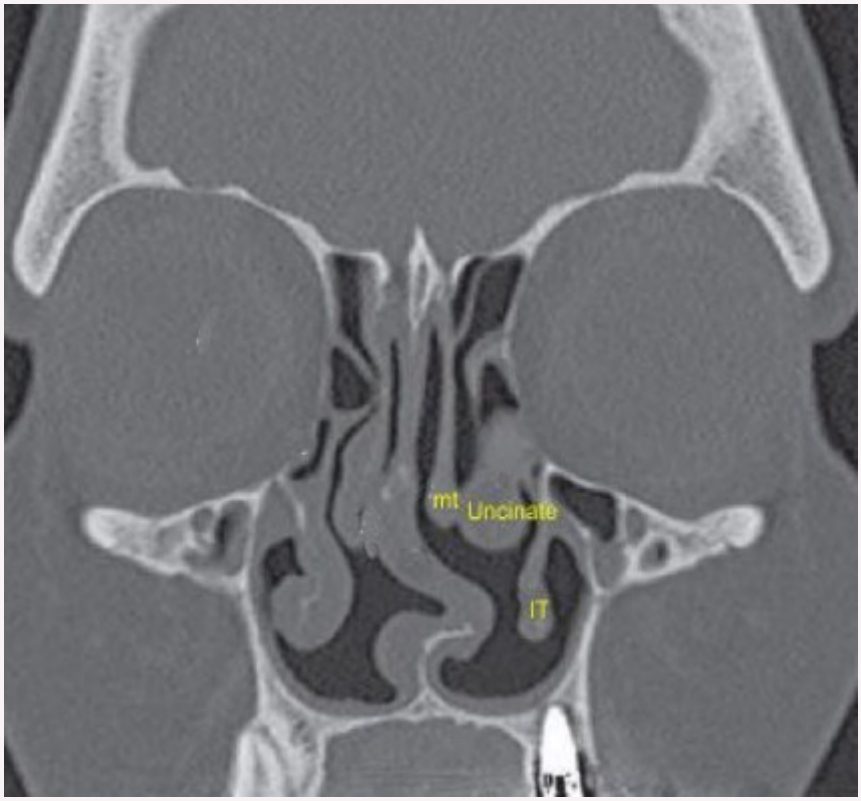


Image of coronal CT nose and sinuses showing Kauffmann's double middle turbinate which is actually a medially deviated uncinate process.

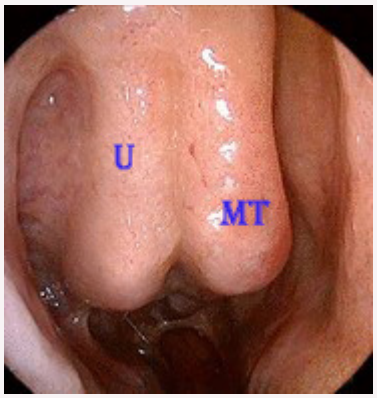


Image showing endoscopic view of double middle turbinate

U - Uncinate process

MT - Middle turbinate

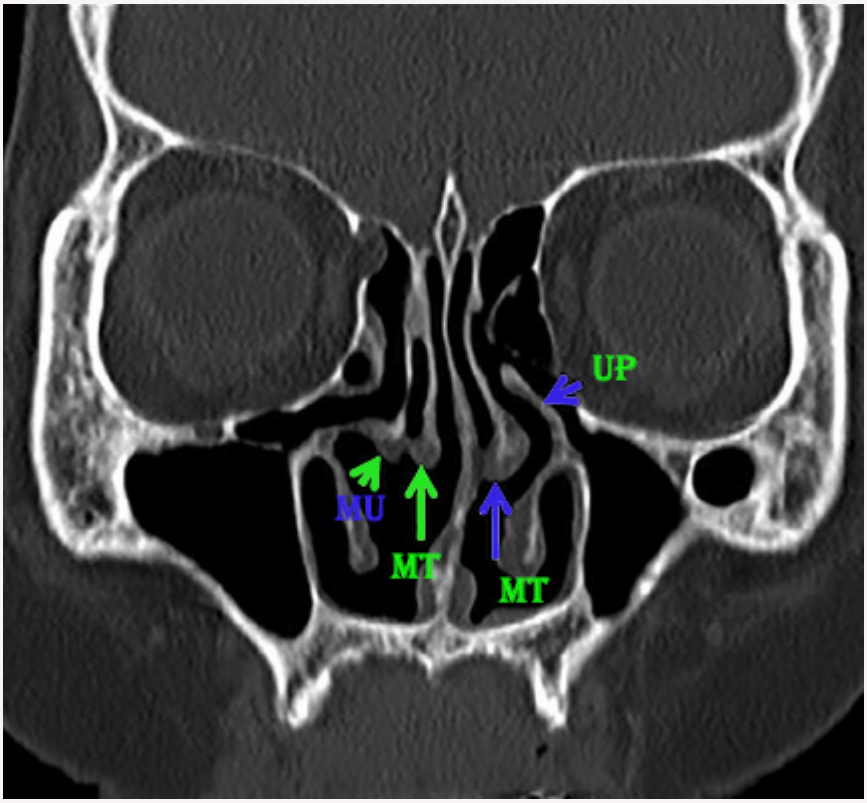


Image showing double uncinate process on right side:

MU - Medialized uncinate

MT - Middle turbinate

UP - Uncinate process

On the right side medialized uncinate pushes and merges with middle turbinate to form what appears to be a double middle turbinate which is a normal anatomic variant.

Paradoxical Middle turbinate:

Paradoxical middle turbinate is a rare developmental cause of nasal obstruction. It refers to an inferomedially curved middle turbinate edge with the concave surface facing the nasal septum and usually occurs bilaterally. This condition is rarely encountered anomaly and can be easily recognized in CT paranasal sinuses. This variant could lead to significant narrowing of the middle meatus and impede the normal drainage of paranasal sinusesdue to OMC obstruction. When associated with concha bullosa, it could lead to potential nasal obstruction.

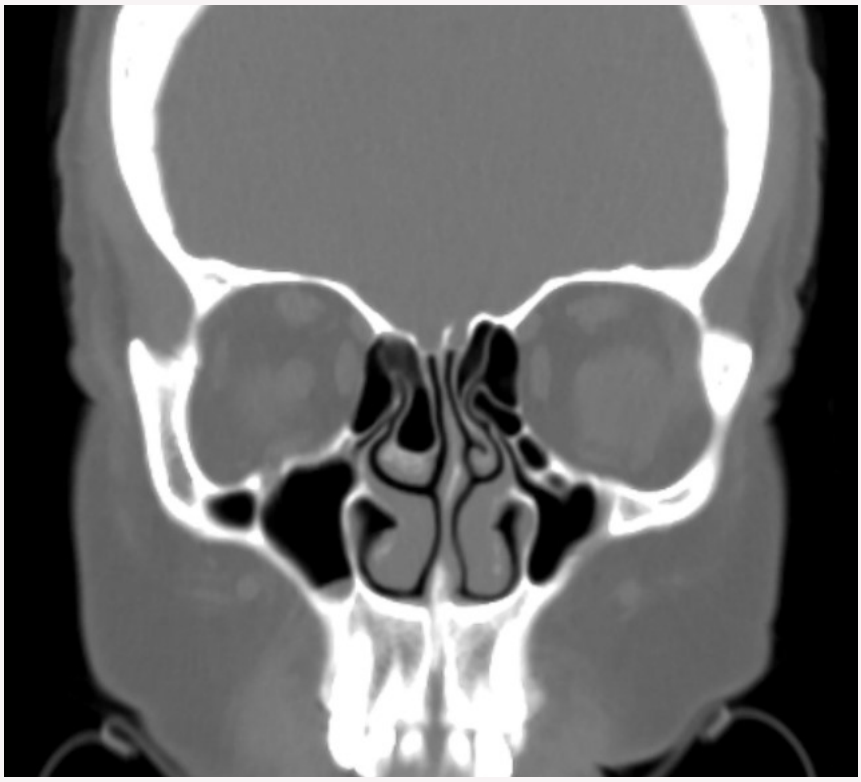


Image showing coronal CT nose and sinuses demonstrating paradoxical middle turbiante on the left side (convexity of the middle turbinate towards the middle meatus) and concha bullosa on the right side. The right middle turbinate is showing its concave margin towards the middle meatus.

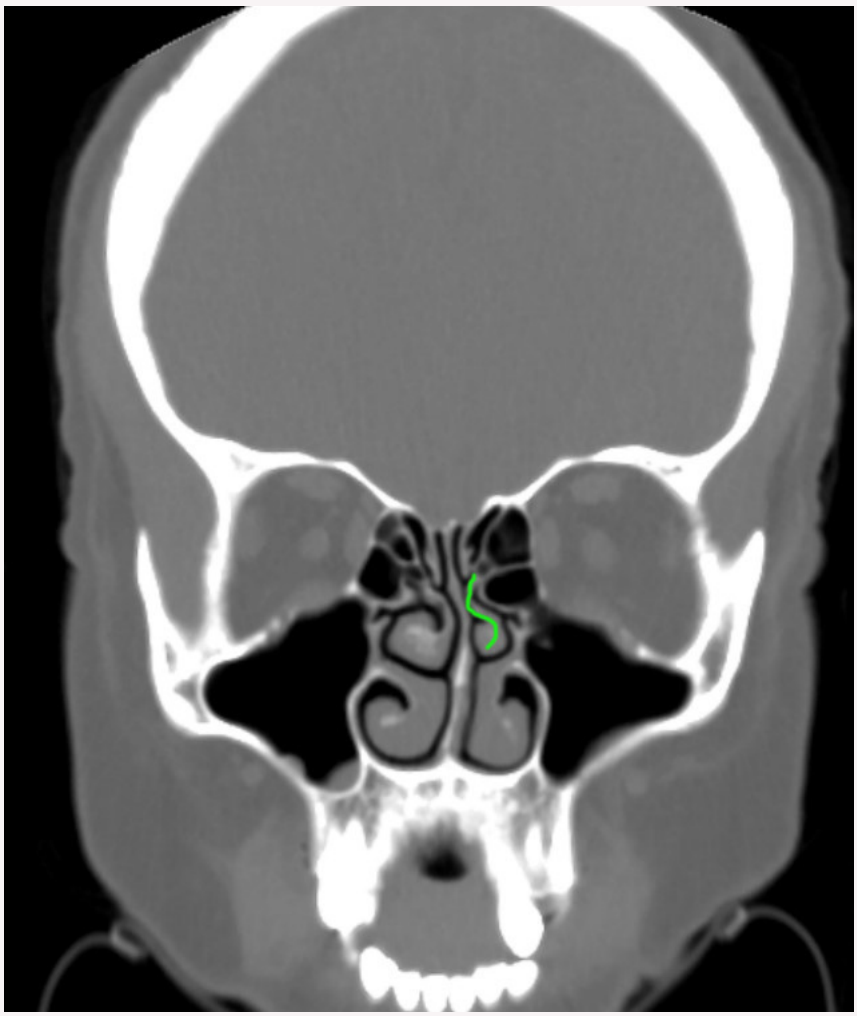


Image showing coronal CT of nose and sinuses showing paradoxical middle turbinate on the left side. (Green curve showing the convex curvature of the middle turbinate towards the middle meatus).

Anatomical abnormalities of inferior turbinate:

Inferior turbinate hypertrophy:

This condition is characterised by enlargement / hypertrophy of inferior turbinate. This is commonly seen in association with deviated nasal septum. Inferior turbinate on the side opposite to the deviation usually undergoes compensatory hypertrophy to fill up the roomy nasal cavity.

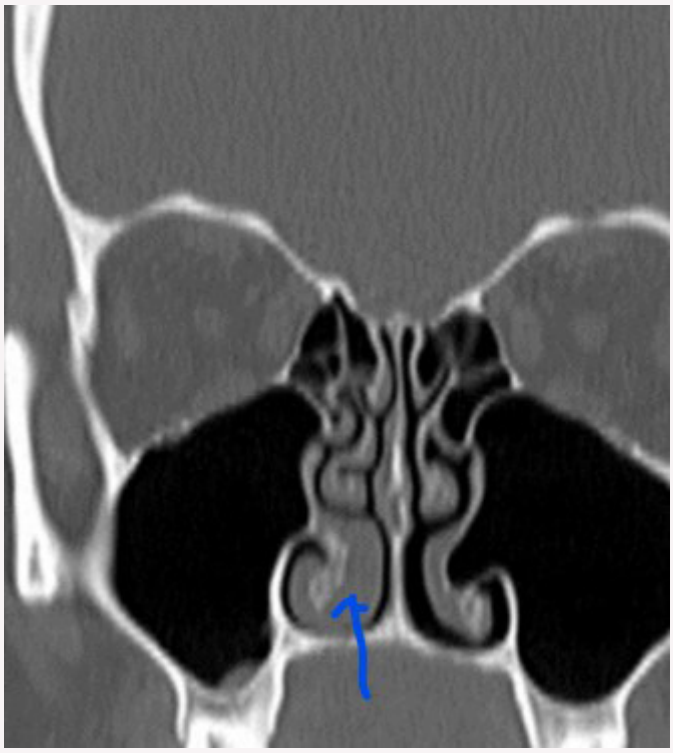


Image showing right inferior turbinate hypertrophy (Blue arrow)

Pneumatized inferior turbinate:

Pneumatization of inferior turbinate is a rare condition. It is virtually impossible to differentiate between hypertrophy of the inferior turbinate and pneumatization clinically. It is only visible in CT images. This was first described as an anatomical variant by Zinreich et al.

Generally pneumatized inferior turbinate is found to be incidental in nature and asymptomatic. Large pneumatized inferior turbinate can cause significant reduction in the nasal valve cross sectional area causing obstructive symptoms. In rare instances there could be obstruction of nasolacrimal duct causing epiphora.

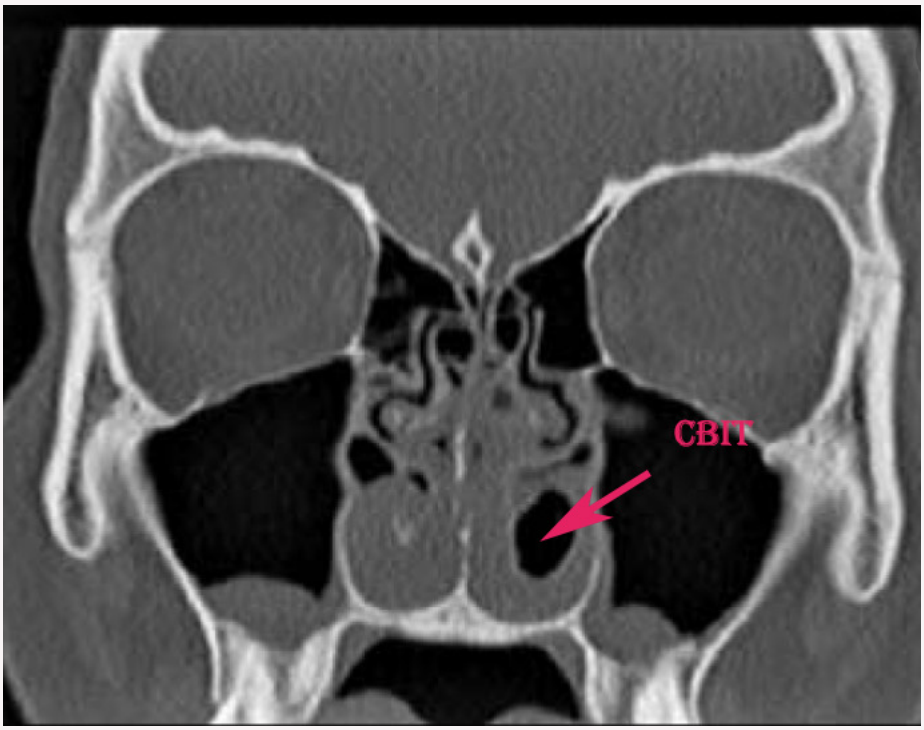


Image showing coronal CT of nose and sinuses showing air cell inside left inferior turbinate

CBIT - concha bullosa inferior turbinate

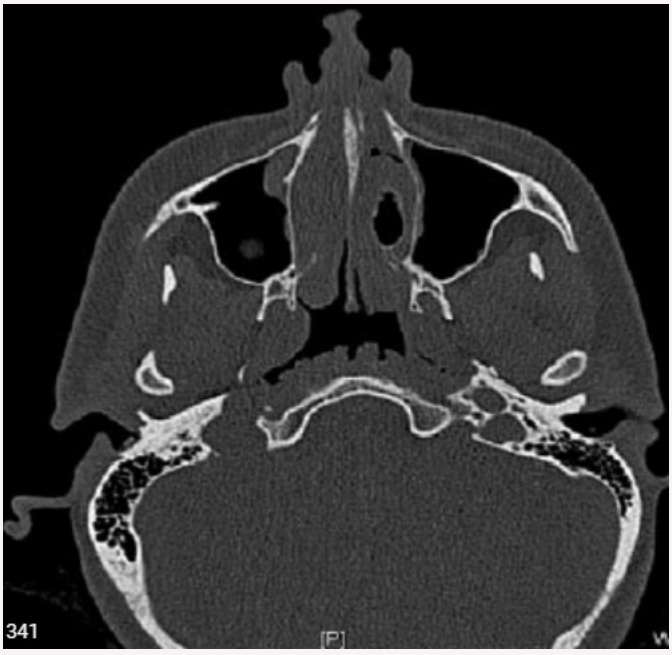


Image showing axial CT nose and sinuses showing pneumatized inferior turbinate on the left side

Bifid inferior turbinate:

This is a rare anatomical abnormality which is an incidental finding. It does not cause any symptoms. It could be associated with missing / absent uncinate process. This anomaly represented two seperate turbinates originating from the same site. The superior part of the bifid inferior turbinate may have been formed by severe medial displacement and inferior rotation of the uncinate process and that the bifid inferior turbinate is an anatomical abnormality of the uncinate process.

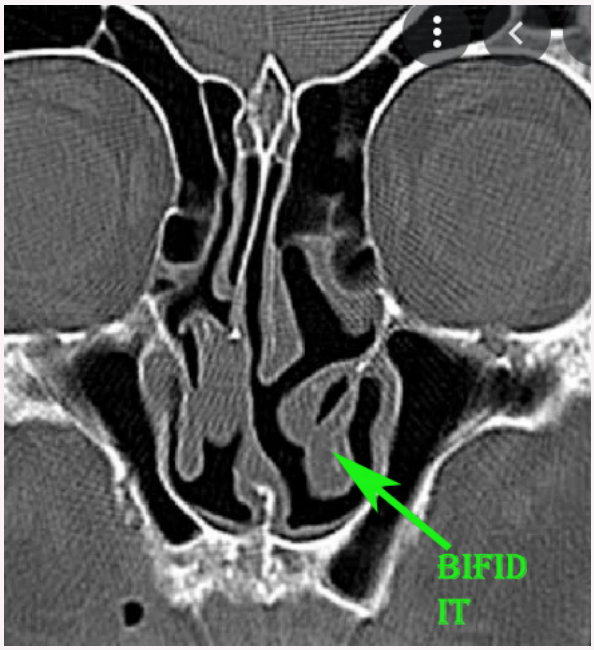


Image showing bifid inferior turbinate

Anatomical variations of Uncinate process:

Uncinate process is a stable structure situated on the lateral walls of the nasal cavity. Its function has not been fully explained. Probably, it could play a role in ventilatory process, preventing non-sterile inspired air from coming into contact with sinus surfaces, while directing the sterile expired air towards the sinuses.

This is the key component of the osteomeatal complex. Uncinate process is a thin, semi-circular bony process of variable length and covered with mucosa. It can be located either frontally and inferiorly or anteriorly and superiorly to the inferior turbinate's ethmoidal process. On its posterior side, the uncinate bone has a superior edge forming the lower margin of the hiatus semilunaris, while the bulla of ethmoidalis forms the upper margin of the hiatus. Inability to understand the variations of uncinate process prior to surgery can lead to various iatrogenic complications.

Superior attachment of uncinate process may show three possible variations:

1. Attachment to lamina papyracea

2. Attachement to the skull base

3. Attachment to the middle turbinate

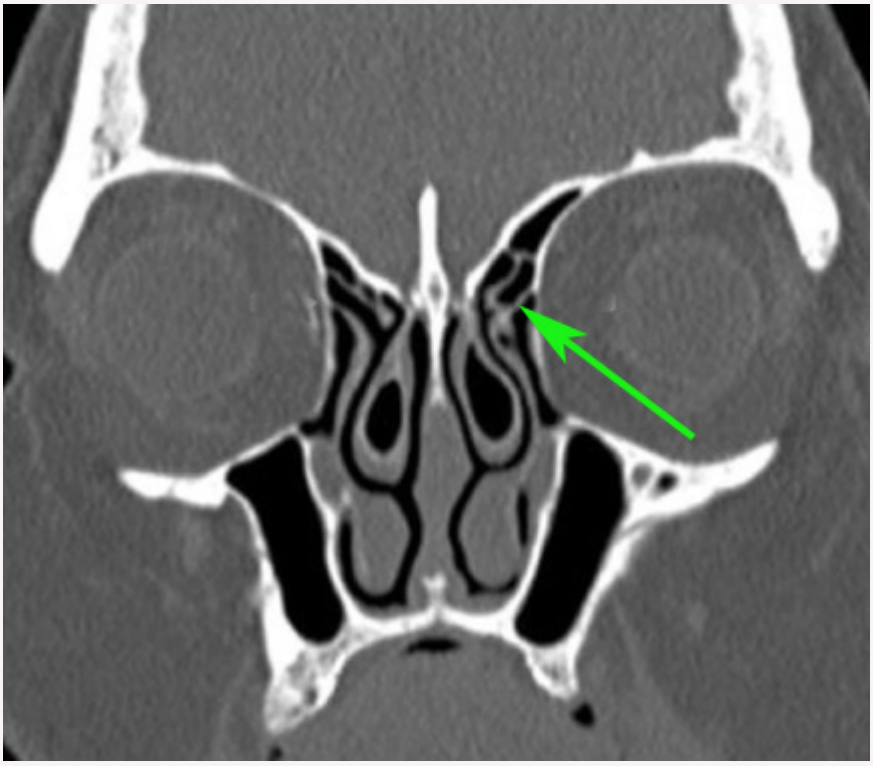


Image showing coronal CT of nose and sinuses showing unicinate process (superior end) being attached to the lamina papyracea (Green arrow). Note the presence of concha bullosa of middle turbinate on both sides.

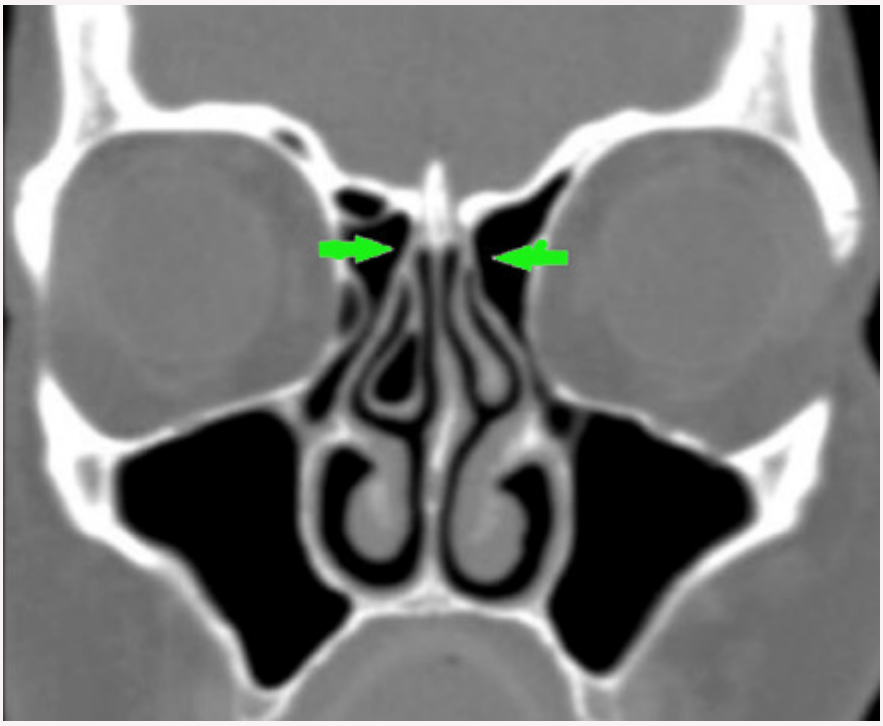


Image showing coronal CT nose and sinuses. Uncinate is seen superiorly to be attached to the skull base (Green arrow).

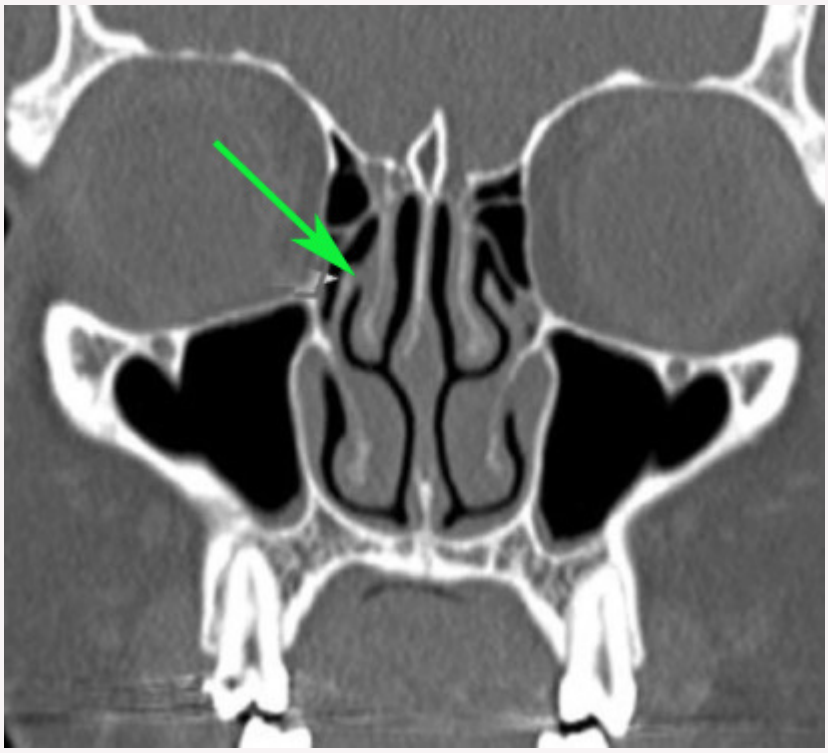


Image showing uncinate process being attached to middle turbinate superiorly (Green arrow)

The variability of the uncinate process anterosuperior attachment affects the drainage of the frontal recess.

Landsberg and Friedman classification of superior attachment of uncinate process:

Type I : Insertion into the lamina papyracea

Type II : Insertion into the posterior wall of agger nasi cell

Type III : Insertion into the lamina papyracea and the junction of the middle turbinate with the cribriform plate.

Type IV : Insertion into the junction of the middle turbinate with the cribriform plate

Type V : Insertion into the ethmoid skull base

Type VI : Insertion into the middle turbinate

Uncinate bulla:

Aeration of uncinate process is also known as the Uncinate bulla. The exact cause for this condition still remains unknown despite the existence of many theories. It is postulated that the agger nasi cells stem from the growth of uncinate process. The uncinate bulla is considered to be a variation that can alter the ventilation through the infundibulum, anterior ethmoid cells and frontal recess. This variation increases the width of the uncinate thereby narrowing the infundibulum.

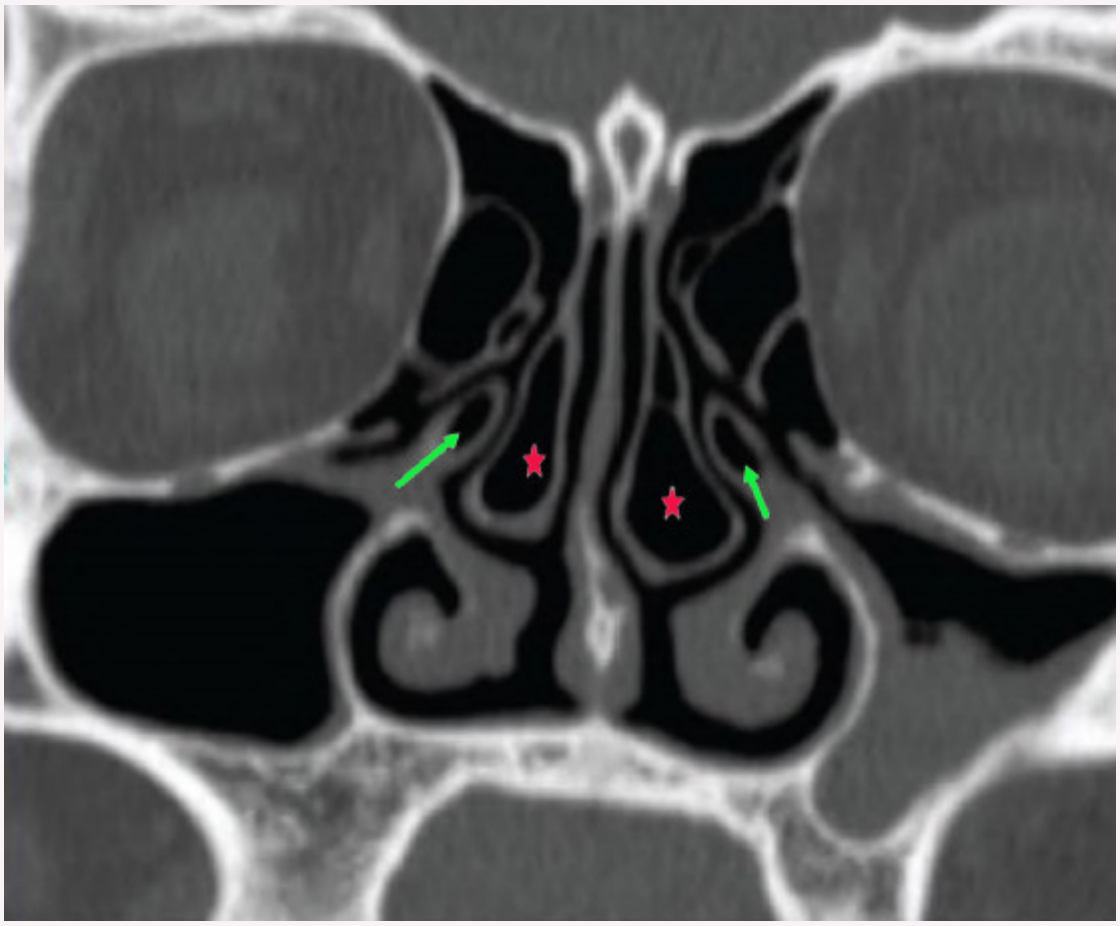


Image showing pneumatized uncinate proess on both sides (Green arrow) and concha bullosa of middle turbinate (Red star). Note there is considerable narrowing between the unicinate process and bulla ethmoidalis. Minor oedema in this region is sufficient to cause drainage block in this area

Deviation of the tip of uncinate process:

The tip of the uncinate process can show lateral deviation, obstructing the infundibulum of medially deviated affecting the middle meatus. Rarely it can be spiral occluding the middle meatus.

Atelectactic uncinate process:

The free end of uncinate process could be hypoplastic and could be attached to medial orbital wall or inferior section of lamina papyracea. This condition is seen together with an opacified hypoplastic maxillary sinus. If this condition is not identified radiologically, it can cause complications like injury to orbit and optic nerve during uncinectomy.

Image showing hypoplastic right uncinate process in coronal CT nose and sinuses

Note hypoplastic right maxillary sinus (opacified)

Bulla ethmoidalis:

This is also known as the middle ethmoid air cell. It is the largest and the most consistent of ethmoid air cell system. Some authors consider Bulla ethmoidalis as belonging to anterior ethmoid group.

This air cell is located posterior to the frontal recess and is enclosed laterally by lamina papyracea. This air cell forms the roof of the middle meatus.

Variations of bulla can be classified into three types:

Simple bulla: This is commonly seen in 50% of individuals. It has a single cavity which usually communicates in the hiatus semilunaris.

Compound bulla: This is seen in 25% of individuals. It has 2-3 seperate compartments and communicates with the hiatus semilunaris.

Complex bulla: This is seen in 25% of individuals. It has 2-3 seperate compartments that com-

municate with the hiatus semilunaris, ethmoid infundibulum or superior meatus.

Bulla ethmoidalis is formed by pneumatization of bulla lamella and the degree of pnuematization is highly variable. In its extreme form (giant pneumatization of bulla), it could fill the entire middle meatus. Failure of pneumatization of the ethmoid bulla is termed as torus ethmoidalis.

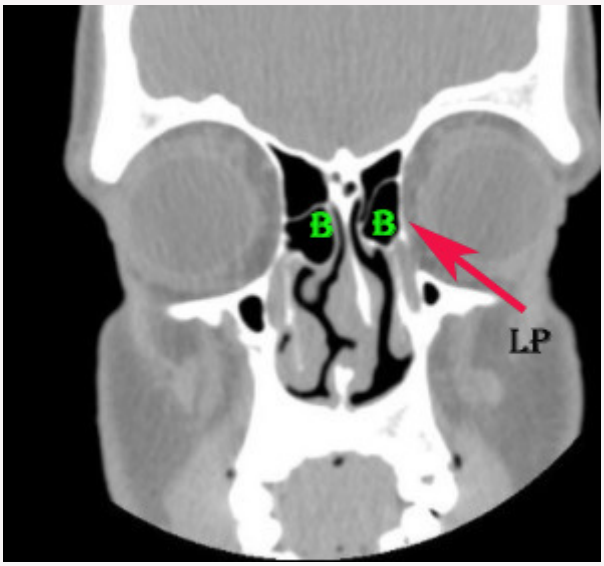


Image showing coronal CT of nose and sinuses

B - Bulla ethmoidalis

LP - Lamina papyracea

Note: Lamina papyracea forms the lateral boundary of bulla

Medially it is bounded by the middle turbinate

Image showing coronal CT of nose and sinuses showing compound bulla on the right side (B). This type of bulla usually drains into hiatus semilunaris

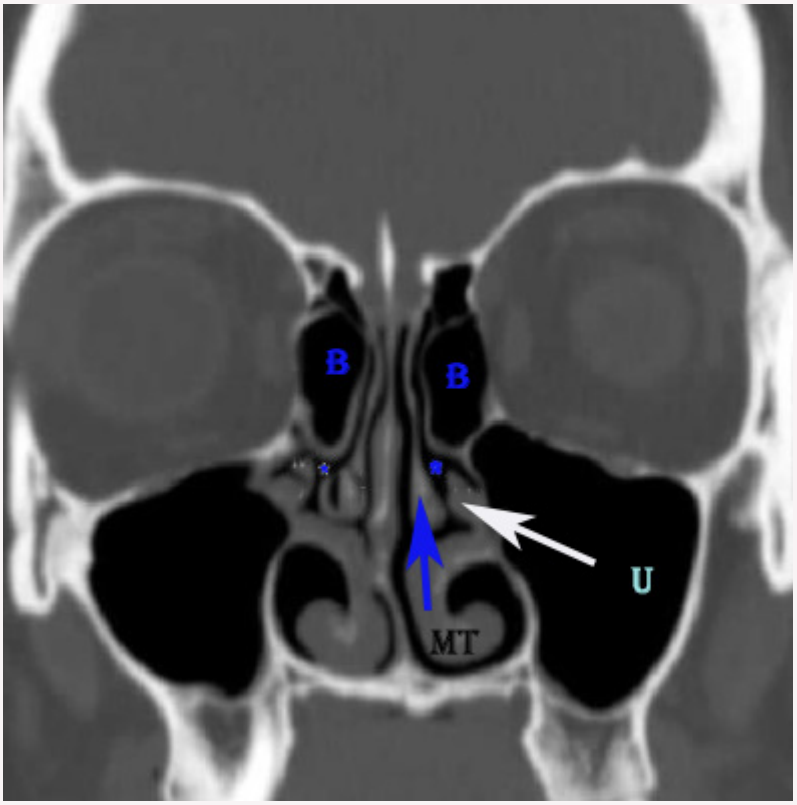


Image showing coronal CT of nose and sinuses showing a large bulla ethmoidalis on both sides.

B - Bulla

U - Uncinate process

MT - Middle turbinate

**** - Middle meatus***

Note- Presence of a large bulla has a tendency to obliterate frontal drainage channel causing frontal sinus obstruction.

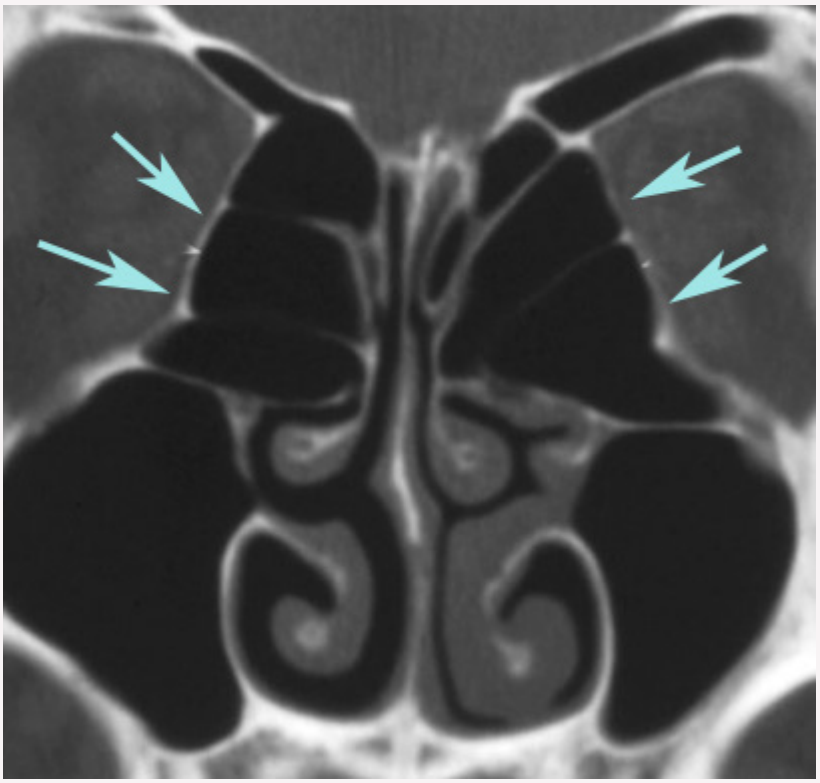


Image showing coronal CT of nose and sinuses with a huge bulla ethmoidalis on both sides encroaching into the middle meatus

Agger Nasi cell:

Agger nasi air cells belong to the most anterior group of ethmoid air cells. It lies anterolateral and inferior to the frontal recess and anterior and above the attachment of the middle turbinate. These cells are located within the lacrimal bone. These cells are related laterally to orbit, the lacrimal sac and the nasolacrimal duct.

These cells are seen in nearly 90% of patients and should not be confused with Haller cells (which is located along the medial floor of the orbit) or supraorbital cells located in the orbital roof.

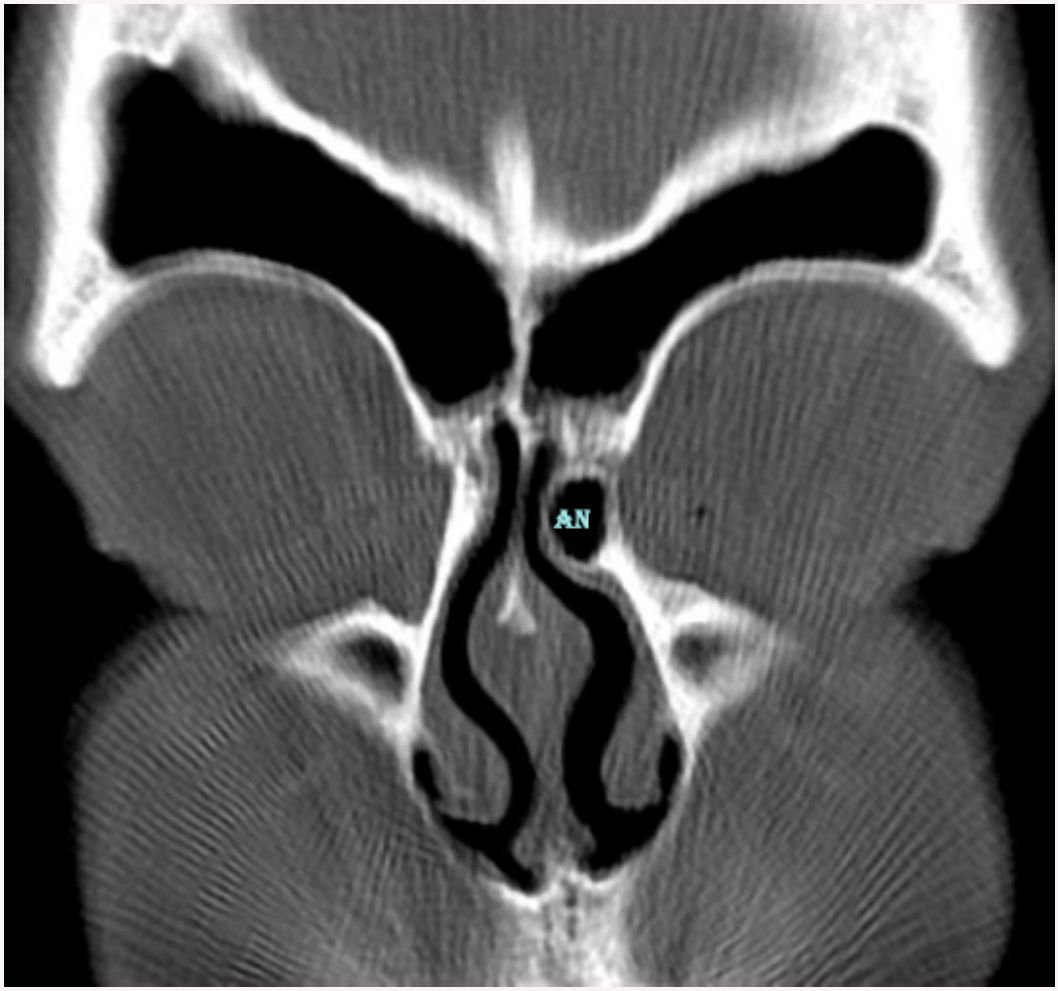


Image showing coronal CT of nose and sinuses showing Agger nasi cell (AN).

Note its relationship to the medial wall of orbit.

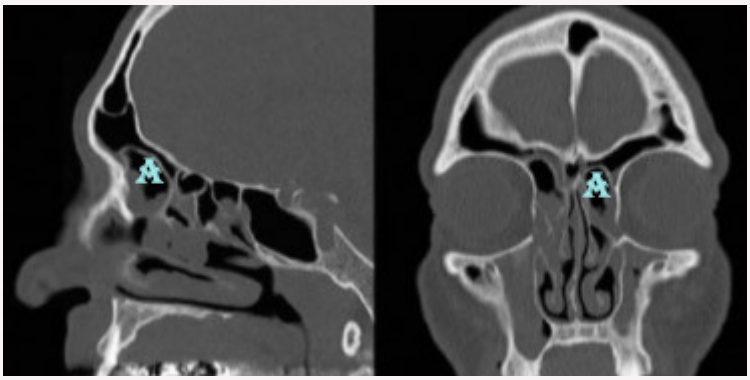


Image showing a large Agger nasi cell on coronal and sagittal sections of CT nose and sinuses (A)

Agger nasi cels contribute to nasofrontal duct obstruction and chronic frontal sinus infection. Enlarged agger nasi cell could encroach the frontal recess area, constricting it causing mechanical obstruction to frontal sinus drainage.

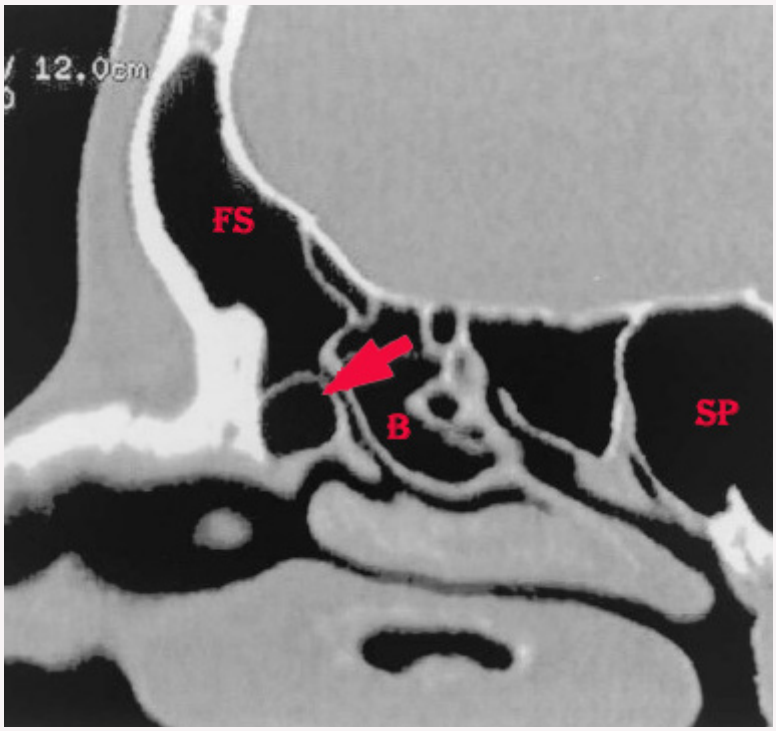


Image showing parasagittal scan showing:

FS - Frontal sinus

Red arrow - Agger nasi cell

B - Bulla ethmoidalis

SP - sphenoid sinus

Enlarged bulla or enlarged agger nasi impedes frontal sinus drainage channel.

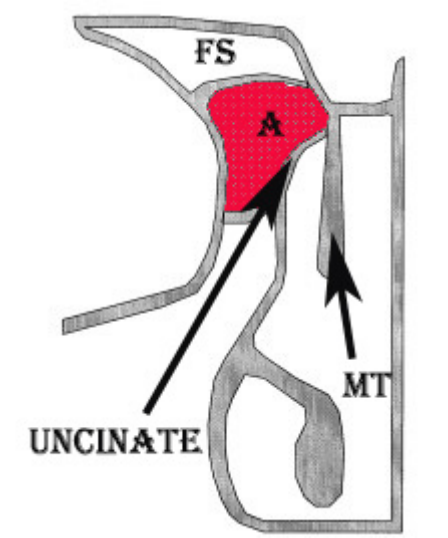


Image showing large agger nasi cell (A) pushing the insertion of uncinate to the middle turbinate

Agger nasi cell is the anterior most of ethmoidal cell. Understanding the anatomical relations between the frontal sinus drainage pathways and the agger nasi would facilitate the understanding of its anatomy. This drinage can be classified as given below:

1. Medial to the agger nasi cell

2. Posterior to the agger nasi cell

3. Posteromedial to the agger nasi cell

The location, dimensions and degree of pneumatization of the agger nasi cell greatly determines the shape, size and diameter of the frontal recess.

Haller cells and their variations:

Haller cells are also known as infraorbital ethmoidal air cells. They are located lateral to the maxillo-ethmoidal suture along the inferomedial orbital floor. These cells are present in about 20% of patients. In many instances they are asymptomatic. Presence of these cells are not thought to be associated with increased incidence of sinusitis.

Presence of these cells could be clinically significant in a number of situations:

1. They can become infected with potential extension into the orbit.

2. It could cause narrowing of the ipsilateral ostiomeatal complex if large, predisposing to obstruction to ipsilateral maxillary antrum.

3. Can inadvertent entry into the orbit if unrecognized at endoscopic surgery.

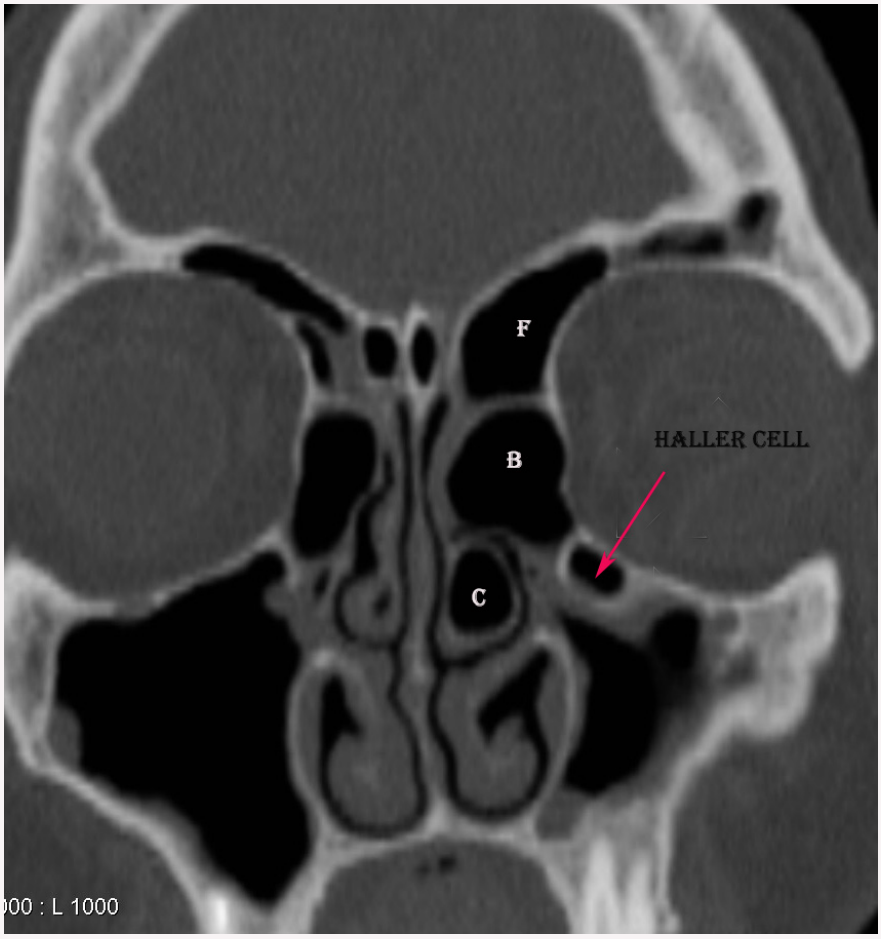


Image showing Haller cell in coronal CT nose and sinuses.
B - Bulla ethmoidalis
F - Frontal sinus C - Concha bullosa

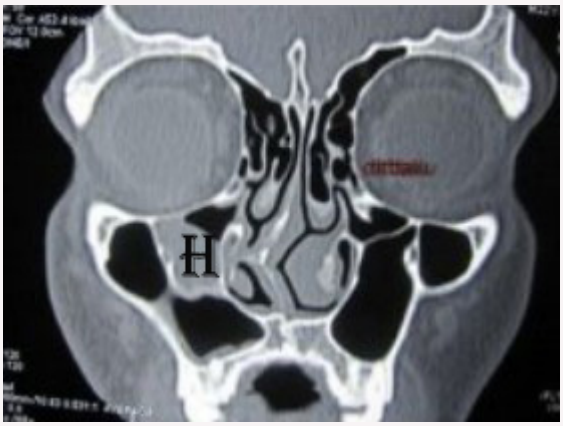


Image showing Haller cell (H) as seen in coronal CT nose and sinuses. The Haller cell is hazy. Enlargement of this cell would cause obstruction to maxillary sinus drainage channel.

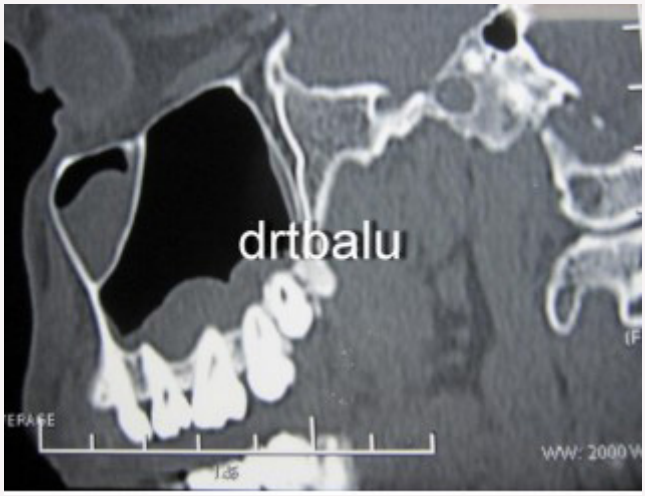


Image showing Haller cell as viewed in lateral view of CT nose and sinuses. It is seeen above and medial to the maxillary sinus.

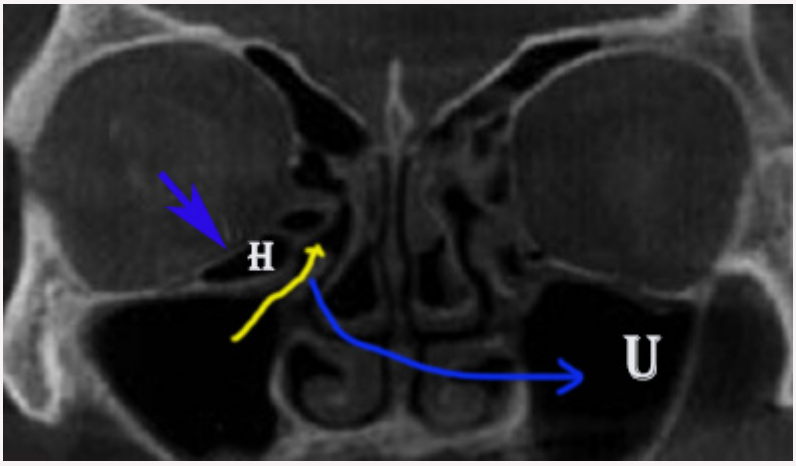


Image showing coronal CT of nose and sinuses showing (H) Haller cell.

U - Uncinate process

Note - Thinning of the inferior orbital wall (blue arrow) by the presence of haller cell. Enlargement of this Haller cell can cause narrowing of the infundibulum (Yellow arrow) causing obstruction to drainage of maxillary sinus.

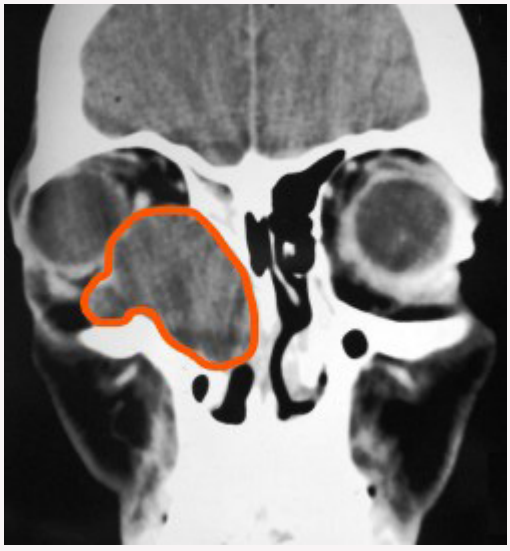


Image showing mucocele of Haller cell causing proptosis. Coronal CT of nose and sinuses

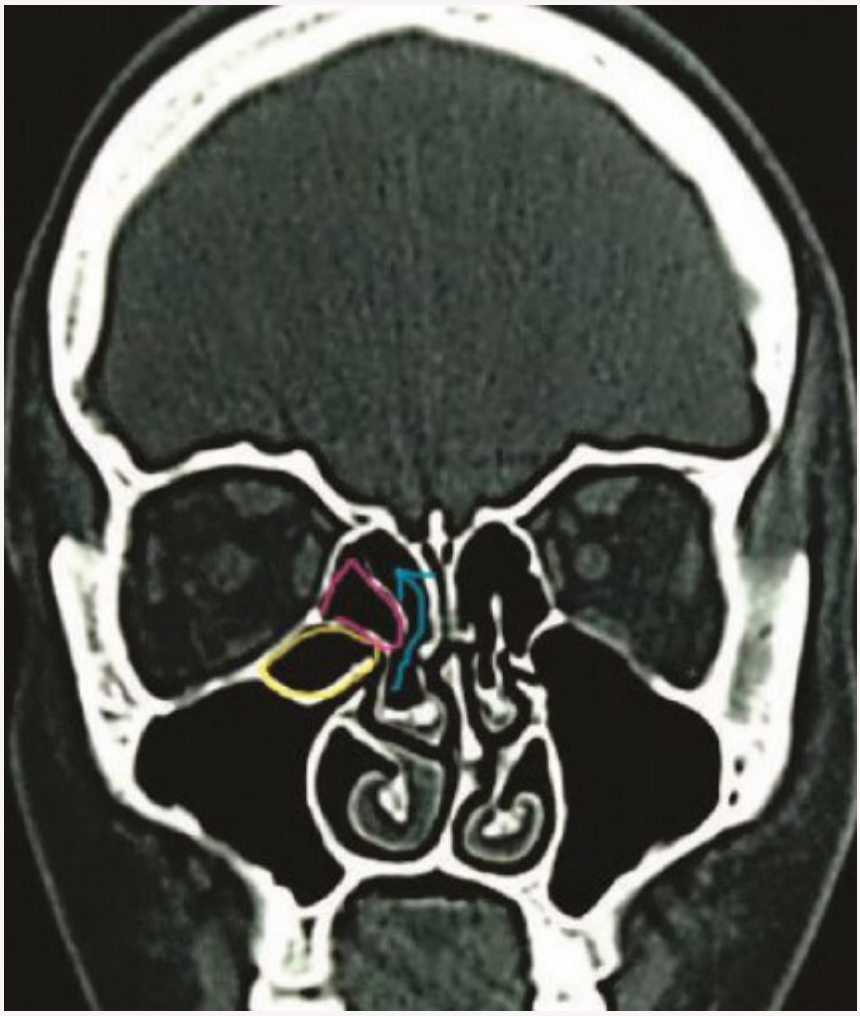


Image showing Right posterior Haller cell with middle turbinate concha communicating with suprabullar recess (Blue arrow)

Image showing Haller cell (H) as seen in axial CT of nose and sinuses. Reader should clearly focus on how Haller cell will look in various paranasal sinus CT views. In this view Haller cell appears posteriorly because the section has been taken axially. Superior position of Haller cell is seen to appear as posterior to maxillary sinus in this view.

Posterior nasal septal air cell:

These air cells are seen in the posterosuperior aspect of the nasal septum and may communicate with the sphenoid sinus. Inflammatory diseases involving the paranasal sinus mucosa could affect these cells. It can resemble an encephalocele. CT / MRI images could clinch the diagnosis.

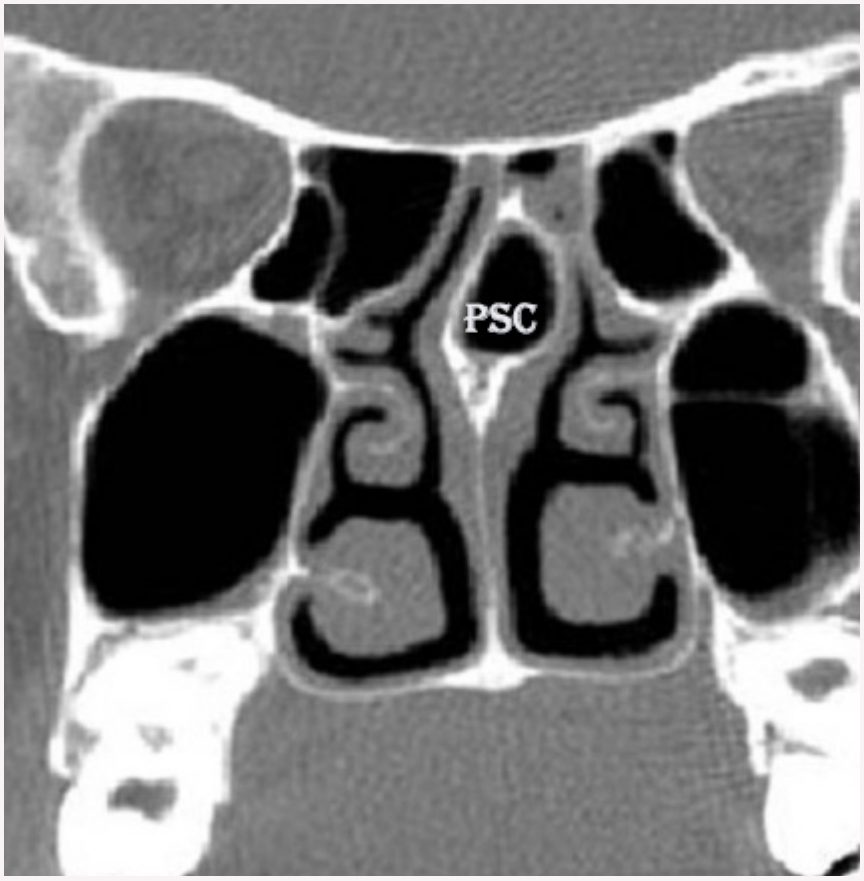


Image of coronal CT of nose and sinuses showing posterior septal air cell (PSC).

Vartiations of optic nerve in relation to sphenoid sinus:

Optic nerve variations inside sphenoid sinus:

Anatomy of optic nerve within sphenoid sinus is highly variable. Optic nerve relationship with sphenoid sinus can be classified into 4 types:

Type I optic nerve:

In this type the optic nerve courses immediately adjacent to the sphenoid sinus without indenting the wall or contact with the posterior ethmoidal air cells. This is the commonest type seen in nearly 75% of individuals.

Type II optic nerve:

In this type optic nerve courses adjacent to sphenoid sinus causing an indentation of the sinus wall, but without contact with the posterior ethmoidal air cell.

Type III optic nerve:

In this type the optic nerve courses through the sphenoid sinus, with at least 50% of it being surrounded by air.

Type IV optic nerve:

Optic nerve lies immediately adjacent to the sphenoid and posterior ethmoid sinuses.

Image showing Type I optic nerve

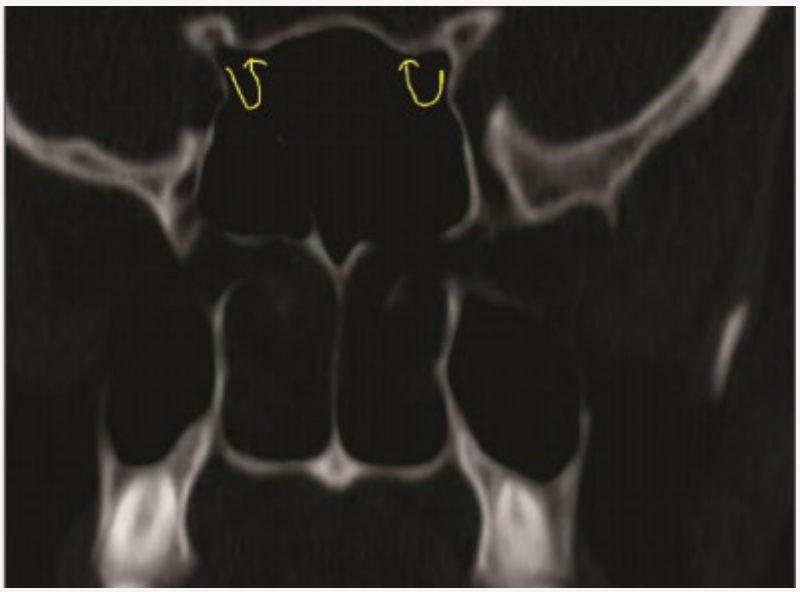


Image showing Type II optic nerve

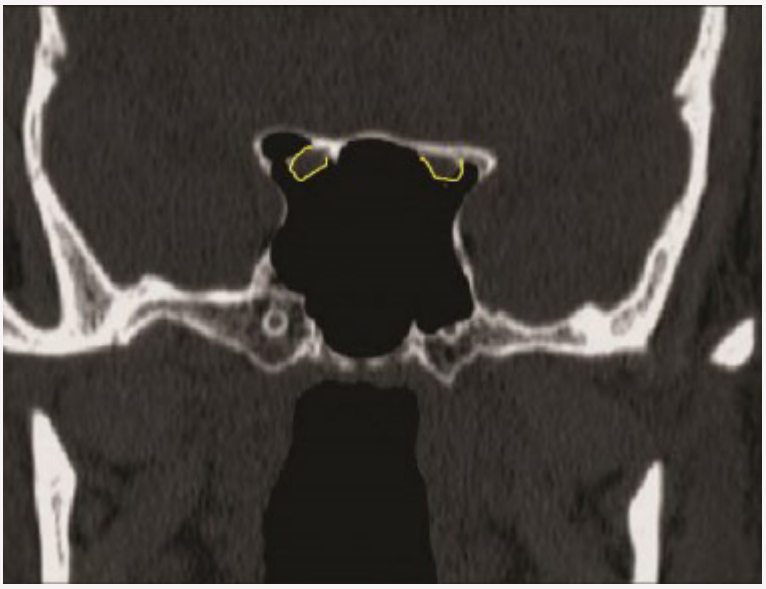


Image showing type III optic nerve

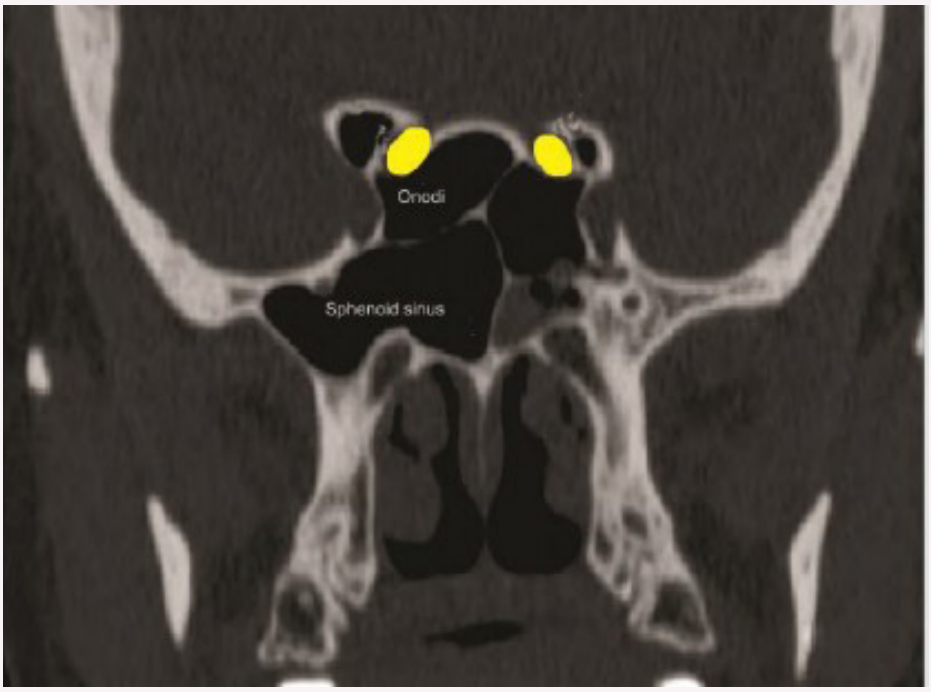


Image showing type IV optic nerve

Hypoplastic sinuses:

Hypoplasia of paranasal sinuses are very rare. It can lead to problems in diagnosis as they could commonly be misdiagnosed as infections / neoplasms involving sinuses. Surgical attempts in these patients will be rather difficult and fraught with danger. Commonly reported hypoplasia involves maxillary sinuses. Incidence of maxillary sinus hypoplasia ranges between (1.5-10%). Majority of these patients were asymptomatic and hypoplasia involving maxillary sinuses were identified only on routine radiology.

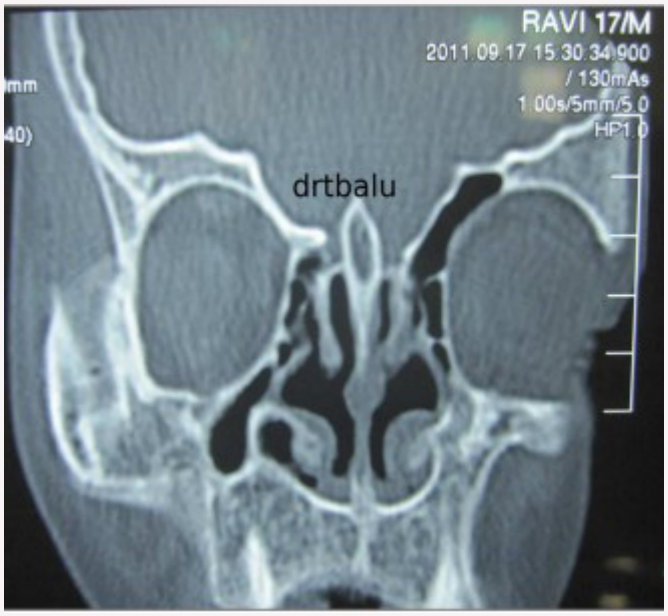


Image showing coronal CT of nose and sinuses demonstrating hypoplasia of maxillary and frontal sinuses

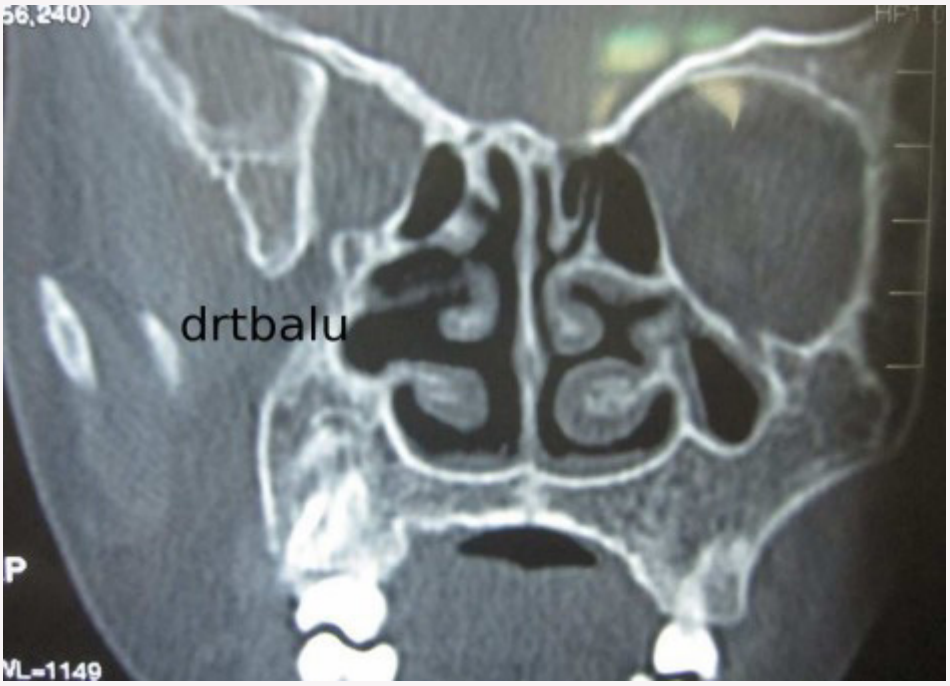


Image showing total aplasia of right maxillary sinus and hypoplasia of left maxillary sinus

Hypoplasia is common in:

1. Frontal sinus

2. Sphenoid sinus

3. Maxillary sinus (rare)

Causes for hypoplastic maxillary sinus:

Hall's hypothesis:

Hall proposed that intrauterine developmental anomalies to be the cause for maxillary sinus hypoplasia.

Wasson's hypothesis:

Wasson postulated that sinus infections during the first year of life could cause maxillary sinus

hypoplasia.

Bolger's classification of maxillary sinus hypoplasia:

Bolger was the first to associated hypoplasia / aplasia of uncinate process with hypoplasia of maxillary sinus. He considered ethmoid and maxillary sinuses to be intimately related embryologically. He suggested that developmental anomalies involving uncinate process will lead to hypoplasia of maxillary sinus also. He classified hypoplasia of maxillary sinuses into three types:

Type I : Mild sinus hypoplasia. Normally developed uncinate process, well developed infundibulum with varying degrees of mucosal thickening.

Type II : Significant maxillary sinus hypoplasia, hypoplastic / absent uncinate process, poorly defined or absent infundibulum, total opacification of the affected sinus.

Type III : Profound hypoplasia of maxillary sinus, absent uncinate process.

Geraghty and Dolan's diagnostic criteria for diagnosing hypoplasia of maxillary sinus:

1. Enlargement of vertical orbital dimension

2. Lateral position of infraorbital neurovascular canal

3. Elevated canine fossa

4. Enlargement of superior orbital fissure

5. Enlargement of pterygopalatine fissure

Sphenoid sinus

Sphenoid sinuses are located at the skull base at the junction of anterior and middle cranial fossae. Pneumatization of sphenoid starts at the age of 3, reaches up to the sella turcia at the age of 7. The entire pneumatization process is completed when the child reaches teen age1. The two sphenoid sinuses are asymmetrical separated by intersinus septum. The posterior attachment of intersinus septum is also variable. It may get attached to the bony carotid canal in the lateral wall of sphenoid sinus. Crude attempts to breakdown this septum in such cases can endanger internal carotid artery causing instantaneous death. Intersphenoid septum should be removed to expose the floor of the sella.

Image showing Coronal CT nose and sinuses showing bifurcated sphenoid intersinus septum attached to the bony covering of internal carotid artery (red color).

It is safer to use true cut forceps to remove intersphenoid septum. Pneumatization of sphenoid sinus can extend into anterior and posterior clinoid process, posterior portion of nasal septum and vomer.

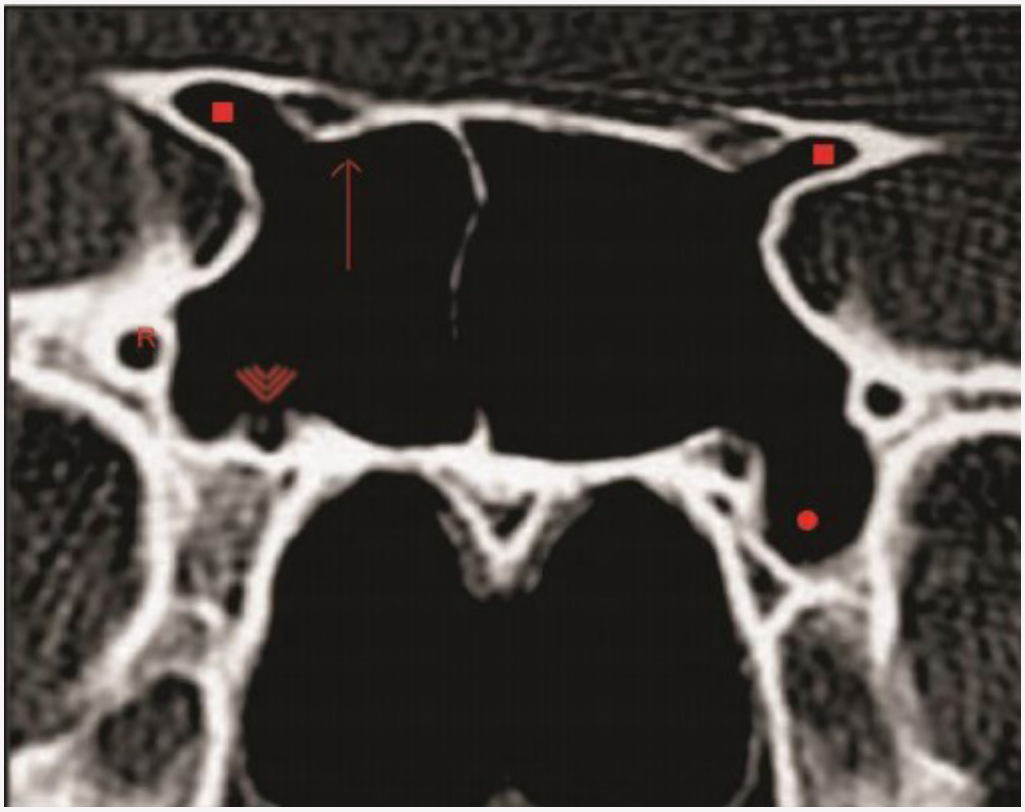


Image showing Coronal CT of nose and sinuses. Red square indicates anterior clinoid process pneumatization, Red dot pterygoid pneumatization, Red arrow optic canal, red arrow head prolapsing vidian nerve in the floor of sphenoid sinus. R indicates foramen rotundum.

Image of Coronal CT of nose and sinuses showing pneumatization of posterior nasal septum

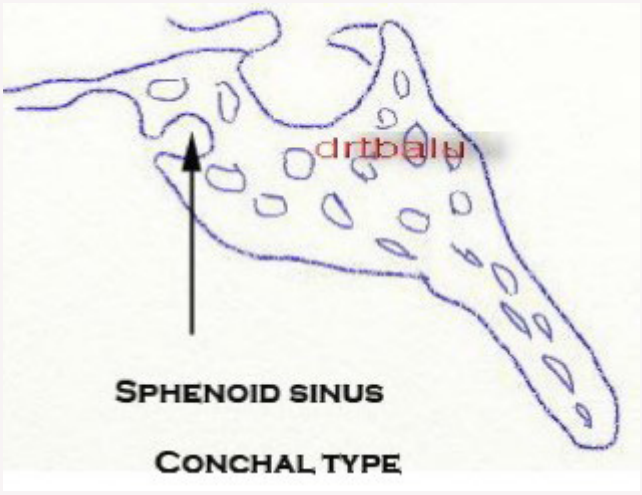
Sphenoid sinus drains through a single ostium into the spheno ethmoidal recess. Sphenoid ostium is situated 7 cm from the base of the columella at anangle of 30° with the floor of the nose in a parasagittal plane. This location corresponds to the half way point in the anterior wall of the sinus. The superior turbinate can be used as an useful intranasal landmark during endoscopic sinus surgery. The postero inferior end of superior turbinate points superiorly and medially towards the sphenoid ostium.

Superior wall of sphenoid sinus usually represents the floor of sella turcica.
Depending on the extent of pneumatization, the sphenoid sinus can be classified into 3 types:

Conchal: The area below the sella is a solid block of bone without pneumatization.

Presellar: The sphenoid is pneumatized upto the level of the frontal plane of the sella and not beyond.

Sellar: This is the most common type of sphenoid pneumatization extending beyond the body of sphenoid, sometimes even up to the clivus.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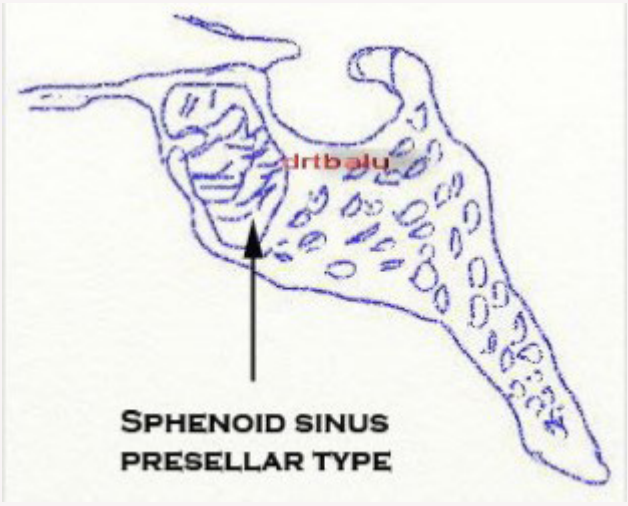
SPHENOID SINUS
CONCHAL TYPE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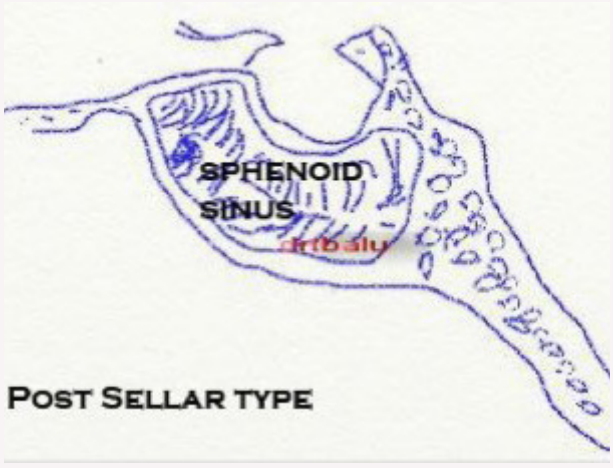
SPHENOID SINUS
PRESELLAR TYPE


SPHENOID
SINUS
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POST SELLAR TYPE

Possible variations of intersinus septum are as follows:

1. A single midline intersinus septum extending on to the anterior wall of sella.
2. Multiple incomplete septae may be seen
3. Accessory septa may be present. These could be seen terminating on to the carotid canal or optic nerve.

Lateral wall of sphenoid sinus: is related to the cavernous sinus. This sinus is formed by splitting of the dura. It extends from the orbital apex to the posterior clinoid process. Cavernous sinus contains very delicate venous channels,cavernous part of internal carotid artery, 3rd, 4th and 6th cranial nerves. It also contains some amount of fatty tissue.

The prominence of internal carotid artery is seen in the postero lateral aspect of the lateral wall of sphenoid sinus. This prominence can be well identified in pneumatized sphenoid bones. On the antero superior aspect of the lateral wall of sphenoid sinus is seen the bulge formed by the underlying optic nerve. These two prominences are separated by a small dimple known as the opticocarotid recess. The optic nerve and internal carotid artery is separated from the sphenoid sinus by a verythin piece of bone. Bone dehiscence is also common in this area.

The roof of the sphenoid (planum sphenoidale) anteriorly is continuous with the roof of ethmoidal sinus. At the junction of the roof and posterior wall of sphenoid, the bone is thickened to form the tuberculum sella. Inferior to the tuberculum sella on the posterior wall is the sella turcica. It forms a bulge in the midline. The bone over the sella could be 0.5 - 1 mm thick.

This may get thinner inferiorly. It is hence easy to breech the sella in this thinnest part. This area can be easily identified by a bluish tinge of the dura which is visible through the thin bony covering.

Currently transphenoid route is considered to be the standard approach to pituitary surgeries.

Sphenomaxillary plate:

When there is excessive pneumatization of sphenoid sinus it can abut themaxillary sinus. The separating wall between these two sinuses is known as sphenomaxillary plate. If present this plate lies next to ethmomaxillary plate.

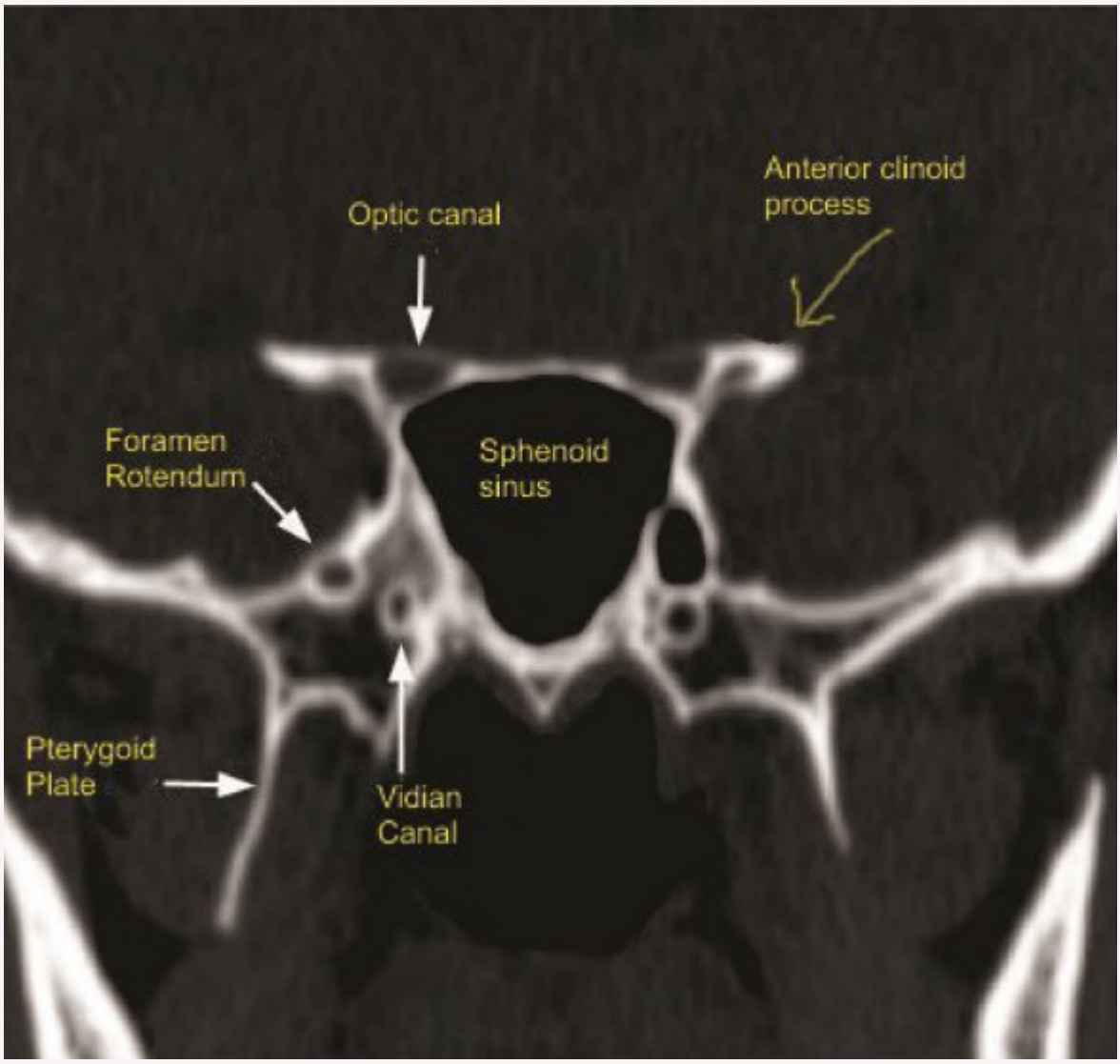


Image showing Coronal CT of nose and sinuses showing Sphenoid sinus and its anatomical relations

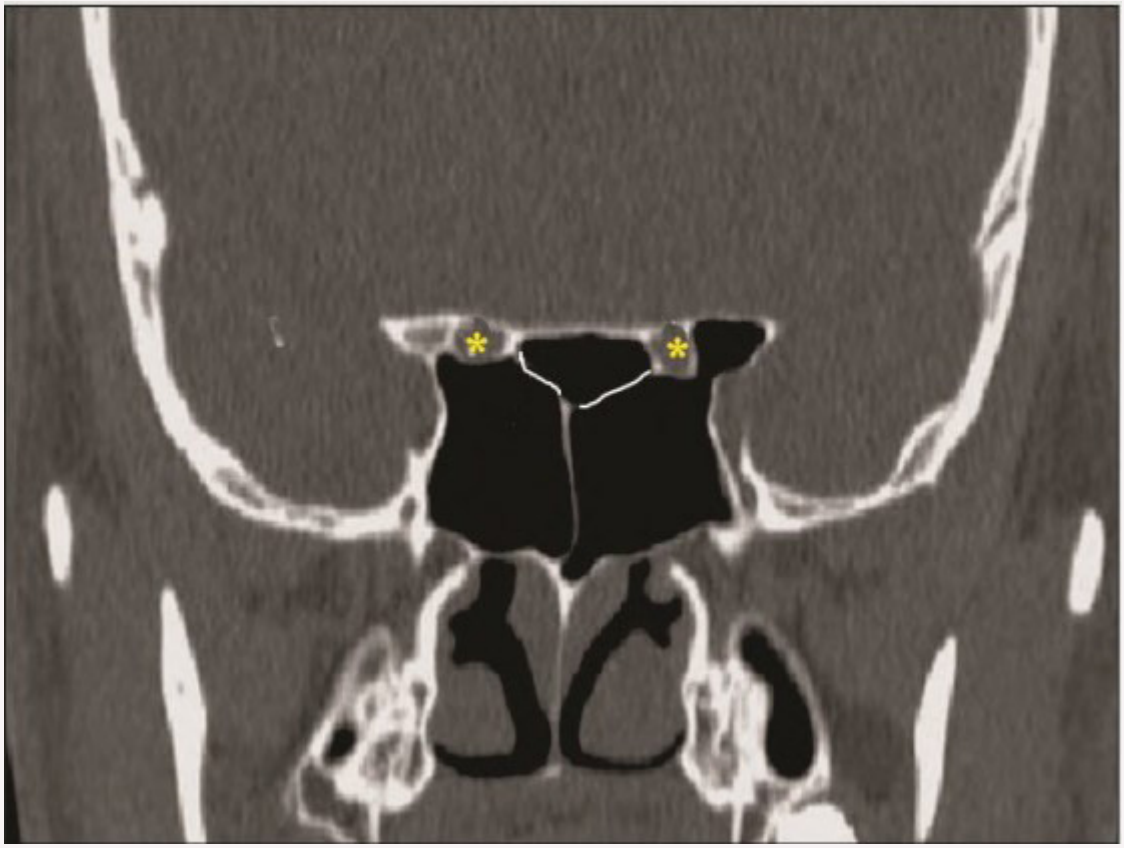


Image showing Coronal CT nose and sinuses showing bifurcating sphenoid intersinus septum attaching to optic nerve.

Intersinus septum can deviate to one side dividing the sphenoid sinus into unequal portions. Accessory intersinus septa are also commonly seen. They can also be attached to internal carotid artery.

The sella turcica is seen as a prominence in the roof of well pneumatisedsphenoid sinus. This bulge is known as the sellar bulge. Sellar bulge is absent in highly pneumatised sphenoid sinus. Hence it is very important to accurately determine the midline when opening the sella. This midline can be confirmed from the base of sphenoid inferiorly or from the remaining anterior sphenoid wall septum attachment superiorly.

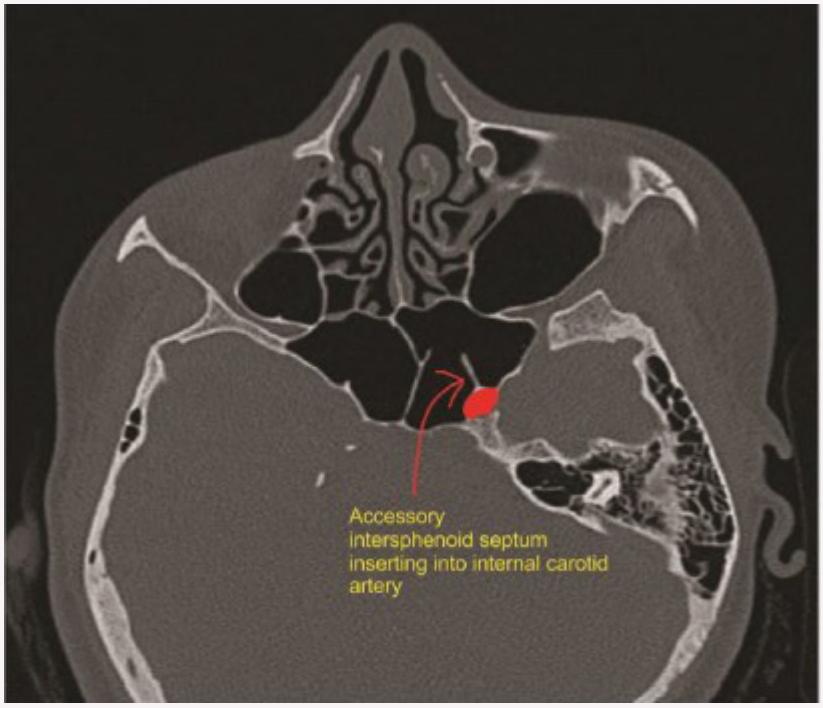


Image showing axial ct nose and sinuses with Accessory intersinus septum seen inside sphenoid sinus getting attached to the internal carotid artery.

Highly pneumatised sphenoid sinus can distort anatomy by attenuating the bony wall over the lateral sphenoid wall. This places the optic nerve and internal carotid artery at risk during surgeries involving this area.

Optic nerve variations inside sphenoid sinus:

Anatomy of optic nerve within sphenoid sinus is highly variable. Optic nerve relationship with sphenoid sinus can be classified into 4 types:

Type I optic nerve:

In this type the optic nerve courses immediately adjacent to the sphenoid sinus without indenting the wall or contact with the posterior ethmoidal air cells. This is the commonest type seen in nearly 75% of individuals.

Type II optic nerve:

In this type optic nerve courses adjacent to sphenoid sinus causing an indentation of the sinus wall, but without contact with the posterior ethmoidal air cell.

Type III optic nerve:

In this type the optic nerve courses through the sphenoid sinus, with at least 50% of it being surrounded by air.

Type IV optic nerve:

Optic nerve lies immediately adjacent to the sphenoid and posterior ethmoid sinuses.

Onodi cell:

This cell belongs to posterior ethmoidal group. This cell also goes by the name Sphenoethmoidal air cell. This cell lies posterior to sphenoid sinus. Very rarely it could lie superior to sphenoid sinus (central onodi air cell). The optic nerve lies very close to this air cell, may be as little as 0.03 mm. Internal carotid artery could also lie close to this air cell. Type IV optic nerve is common in the presence of onodi air cell. Incidence of onodi cell is rather high, one study going to the extent of about 60%9. Infections involving ondi air cells puts optic nerve at risk. If surgeon is not aware of this air cell he could cause inadvertent damage to optic nerve during endoscopic sinus sur gical procedures.

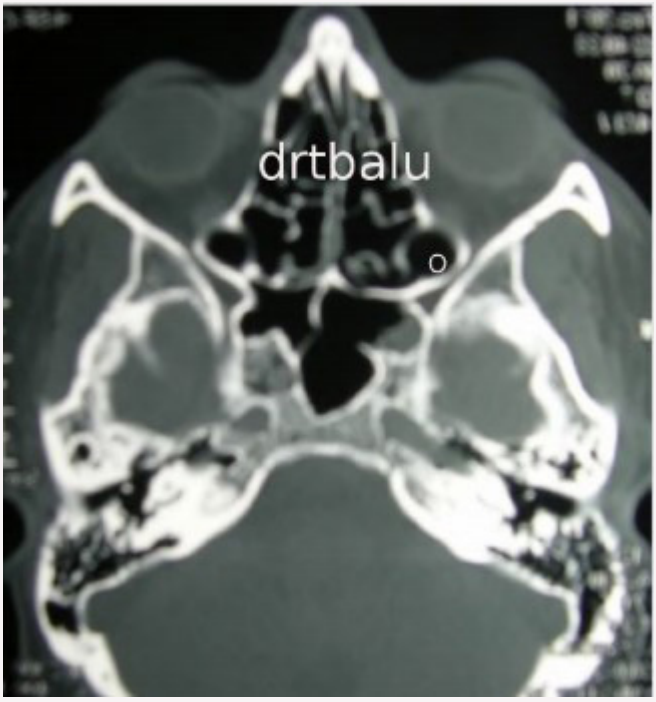


Image showing Axial CT of nose and sinuses showing Onodi cell (o)

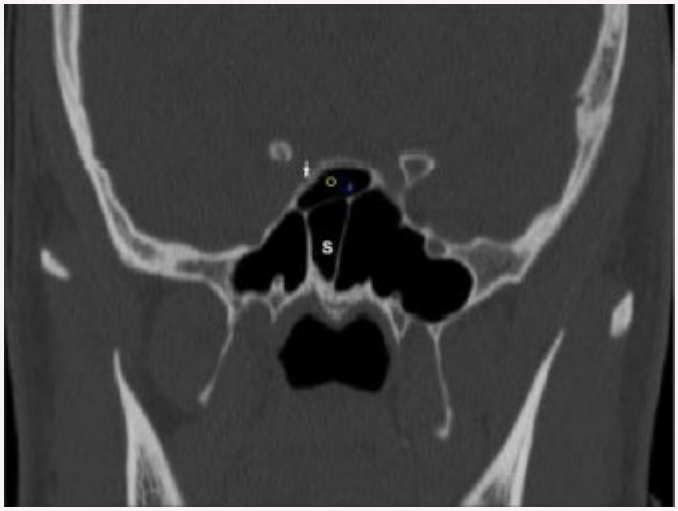


Image showing Coronal CT nose and sinuses showing Onodi cell (s-sphenoid o - onodi)

Vidian nerve and sphenoid sinus:

The vidian nerve is formed by post synaptic parasympathetic fibers and presynaptic sympathetic fibers. This is also known as the "Nerve of pterygoid canal".

Nerves that gets involved in the formation of vidian nerve:

1. Greater petrosal nerve (preganglionic parasympathetic fibers)
2. Deep petrosal nerve (post ganglionic sympathetic fibers)
3. Ascending sphenoidal branch from otic ganglion

Vidian nerve is formed at the junction of greater petrosal and deep petrosal nerves. This area is located in the cartilagenous substance which fills the foramen lacerum. From this area it passes forward through the pterygoid canal accompanied by artery of pterygoid canal. It is here the ascending branchfrom the otic ganglion joins this nerve.

The vidian nerve exits its bony canal in the pterygopalatine fossa where itjoins the pterygopalatine ganglion.

Vidian canal:

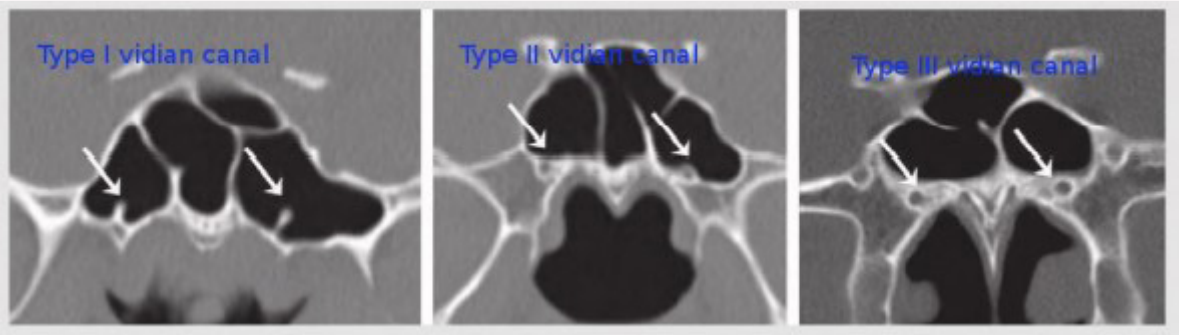
It is through this canal the vidian nerve passes. This is a short bony tunnel seen close to the floor of sphenoid sinus. This canal transmits the vidian nerve and vidian vessels from the foramen lacerum to the pterygopalatine fossa.

According to CT scan findings the vidian canal is classified into:

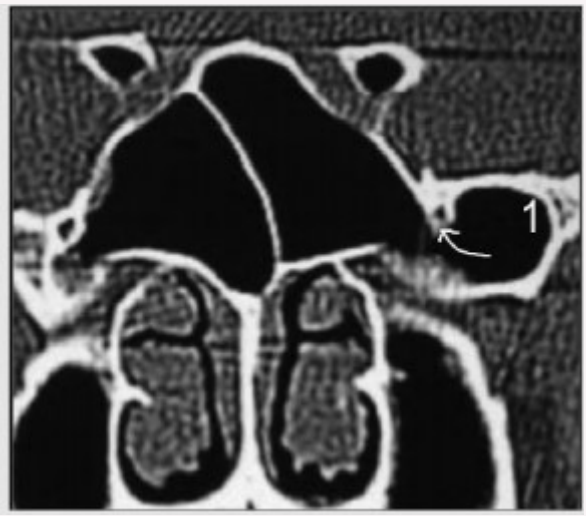
Type I: The vidian canal lies completely within the floor of sphenoid sinus

Type II: In this type the vidian canal partially protrudes into the floor of sphenoid sinus

Type III: Here the vidian canal is completely embedded in the body of sphenoid bone



CT image showing the three types of Vidian canal in relation to sphenoid sinus



Coronal CT image showing (1) pneumatization of left greater wing of sphenoid. Arrow indicates protrusion of maxillary nerve.

The maxillary nerve is found in the maxillary canal (foramen rotundum). This may be dehiscent in some individuals. Pneumatization of greater wing of sphenoid is commonly associated with protrusion of maxillary nerve.

Maxillary sinus

Introduction:

This is the largest of paranasal sinuses. Along with ethmoidal sinus this sinus is present at birth. Maxillary sinus begins its development from the inferior aspect of ethmoidal infundibulum at about 16 weeks.

Dimensions of maxillary sinus at birth:

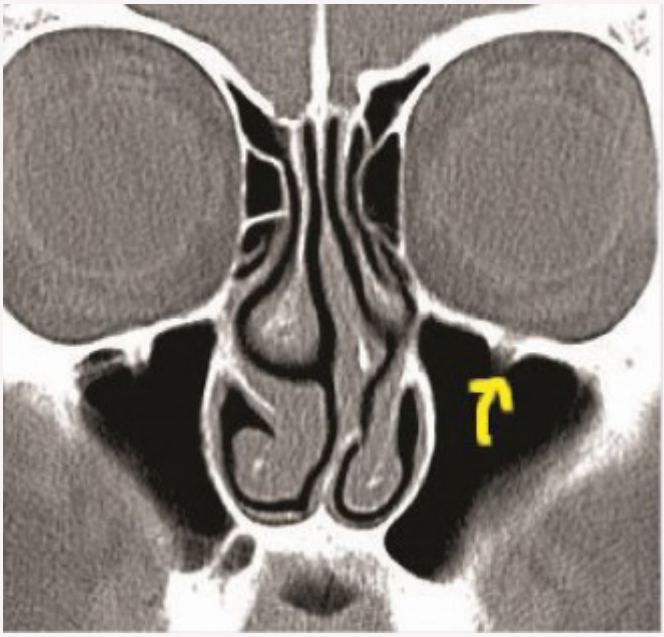
Height - 4mm
Anteroposterior depth - 7 mm
Width - 2.7 mm

Rapid pneumatization of maxillary sinuses continue between ages 1–8. Initially the floor of the maxillary sinus extends just above the level of the floor of the nasal cavity. Following exfoliation and replacement of primordial dentition maxillary sinus pneumatization reaches up to the level of floor of the maxillary sinus. In a child the superior wall of maxillary sinus slopes inferolaterally. As the child grows up this slope gradually becomes reduced to forma straight wall. In adults the maxillary sinus takes the form of pyramid with an interior volume of 15 ml.

Components forming the thin medial wall of maxilla include:

1. Maxilla
2. Inferior turbinate
3. Uncinate process
4. Perpendicular plate of palatine bone
5. Lacrimal bone

Lateral apex of maxillary sinus extends into the zygomatic process of the maxilla. Sometimes it may extend up to the zygomatic bone.
Roof the maxillary sinus is actually the floor of the orbit containing canal for the infraorbital nerve. Sometimes this nerve can be naked bereft of its bony covering. This could be a potential cause for facial pain.



Coronal CT of nose and sinuses showing infraorbital nerve in the roof of maxillary sinus.

The floor of maxillary sinus is formed by the palatine process of maxilla. This point actually lies 1 cm below the level of the floor of the nasal cavity. The maxillary sinus is usually separated from molar dentition by a layer of compact bone. Sometimes this layer of bone could be thin or absent providing a direct route of spread of dental infections into the maxillary sinus.

The maxillary sinus classically demonstrates biphasic growth 4. The first phase of growth occurs during the first 3 years of life while the second growth phase occurs between 7-18 years of age. The anterior wall of maxillary sinus is thinnest over the canine fossa area. It may just be 2mm thick. Since this portion is the weakest portion of the anterior wall of maxilla this is breached intentionally during Caldwel Luc surgery procedures.

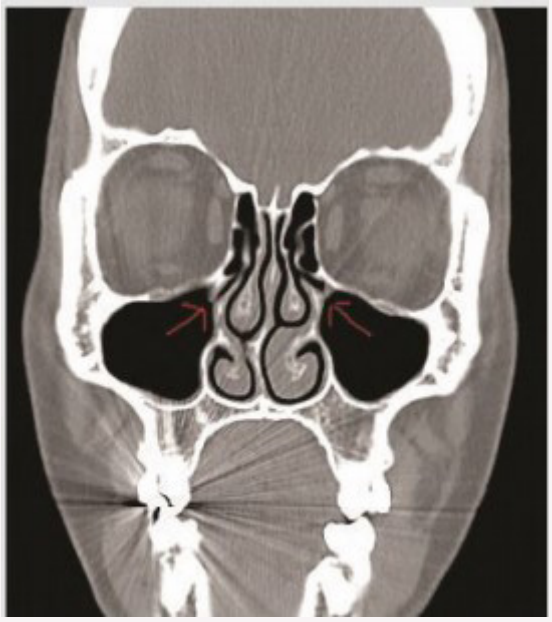
Boundaries of Canine fossa:

Inferior: Bounded by the alveolar ridge
Lateral: Bounded by the canine eminence which is caused by the canine tooth.
Superior: Infra orbital foramen
Medial: Pyriform aperture

Maxillary sinus ostium is placed postero superiorly and hence gravity does not play any role in its drainage. It is only the mucociliary clearance mechanism which clears secretions out of maxillary sinus. Natural ostium may be found at any point along the course of ethmoidal infundibulum. It is more commonly found to open into posterior third of infundibulum. Sometimes accessory ostium could be seen in the medial wall of maxillary sinus. This commonly develops in the posterior fontanel. Widening this accessory ostium does not help in drainage of maxillary sinus because mucociliary clearance mechanism does not allow drainage through accessory ostium.

Differences between natural ostium and accessory ostium

Natural ostium	*Accessory ostium*
Present anteriorly and is not visible under routine direct nasal endoscopic examination.	Present posteriorly and can easily be visualized during routine nasal endoscopic examination.
Oval in shape	Spherical in shape
Oriented transversely	Oriented anteroposteriorly



Coronal CT of nose and sinuses showing natural ostium

Coronal CT nose and sinuses showing maxillary sinuses extending much below the level of floor of the nasal cavity.

Coronal CT of nose and sinuses showing both accessory (red arrow head) and natural ostia (white arrow head)

Septate Maxillary sinus:

Septations involving maxillary sinuses are rather common. They are asymptomatic. These septations are classified into primary and secondary types.

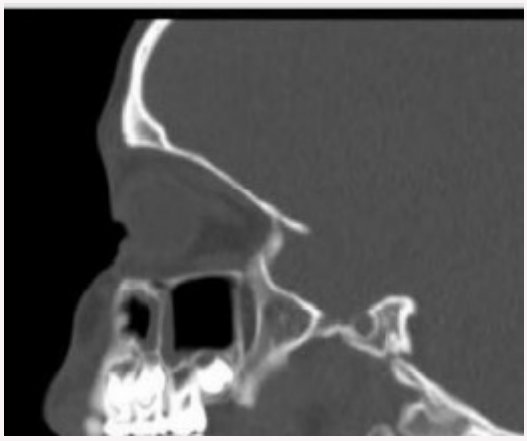
Primary Maxillary sinus septations:

These septa occur after tooth eruption.

Secondary Maxillary sinus septations:

These septa occur after eduntulation. Complete or near complete maxillary sinus septa are really rare. Infections involving maxillary sinus is common in the presence of complete or near complete septa of maxillary sinus.

Coronal CT image of nose and sinuses showing septations of maxillary sinus



Sagittal reformatted CT image of nose and sinuses showing septa in the maxillary sinus

Anatomical dissection studies undertaken by Underwood demonstrated that septa involving maxillary sinus is commonly seen in the posterior segment. Anatomical studies showed maxillary sinus septa to be commonly oriented in sagittal or transversal (medial to lateral). CT imaging is the preferred method in identifying this anatomical variation.

Frontal Sinus

Frontal sinus is a complex and highly variable structure. These anatomic variations have a tremendous impact on the direction of drainage, efficiency of mucociliary clearance mechanism and frontal recess morphology. CT scans of frontal sinus have conventionally being performed with continuous 3mm coronal and axial slices. High resolution multiplanar scanners have made sagittal reformatted images a possibility. These scanners enable imaging in three planes.

Embryology: Sinonasal embryology plays an important role in the anatomical variations seen in various patients. Paranasal sinuses begin their development during the first trimester from the six ethmoturbinals. These turbinals enlarge and progressively coalesce to form the lateral nasal wall. The agger nasi cell develops from the most superior remnant of the first ethmoturbinal.

The remnant from the descending portion of first ethmoturbinal forms the uncinate process. Basal lamella of the second ethmoturbinal pneumatizes to form Bulla ethmoidalis. The basal lamella of third ethmoturbinal forms the basal lamella of the middle turbinate.

Nasal mucosa invaginates at specific points into the lateral nasal wall forming sinus pits. These sinus pits enlarge to from the maxillary, frontal and ethmoidal sinuses. The mesenchyme around these sinus pits resorbs allowing for enlargement of sinus cavities. The point of mucosal invagination gives rise to the sinus ostium. Frontal sinus drainage pathway is complex because of the variable anatomy of agger nasi, anterior ethmoidal cells, and pattern ofinsertion of uncinate process.

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process.

Frontal sinus drainage pathway: The frontal sinus grows and expands into the diploic space of frontal bone from the frontal sinus ostium. Each frontal sinus grows independently of the other. Their growth or lack of it is dependent on the ventilation, drainage and growth of surrounding sinuses and skull base.
The frontal sinus narrows inferomedially into a funnel shaped area known as frontal sinus ostium. Anterior wall of this area is bounded by a bony ridge known as "nasal beak". The frontal sinus ostium is oriented perpendicular to the posterior wall of the sinus at the level of anterior skull base.

Some authors divide frontal sinus drainage pathway into superior and inferior compartments. The superior compartment is formed by the union of adjacent air spaces at the antero inferior portion of the ethmoid bone. Its size and shape varies with the variable anatomy of fronto ethmoidal air cells. The superior compartment communicates directly with the inferior compartment. The inferior compartment is a narrow passage way formed by the ethmoidal infundibulum or the middle meatus. If the uncinate process gets attached to the skull base the inferior portion is formed by the ethmoidal infundibulum. On the contrary if the uncinate process gets attached to the lamina papyracea the inferior compartment is formed by the middle meatus.

Frontal recess area: Is anatomically defined as the most anterior and superior part of anterior ethmoidal complex. This is precisely where from the frontal bone gets pneumatized. In the sagittal plane the frontal recess appears like an inverted funnel.

In the sagittal plane the frontal recess appears like an inverted funnel. It opens superiorly into the frontal sinus ostium. The lateral wall of frontal recess area is formed by lamina papyracea. Its medial wall is formed by the vertical attachment of middle turbinate.

Its posterior wall is highly variable, and is formed by the bulla ethmoidalis if it reaches up to the level of skull base. A large bulla could cause narrowing of this critical area obstructing frontal sinus drainage channel. Any imaging modality should critically examine this area where pathology could lurk. The agger nasi cells and the uncinate process play a role in the formation of the floor of this area.

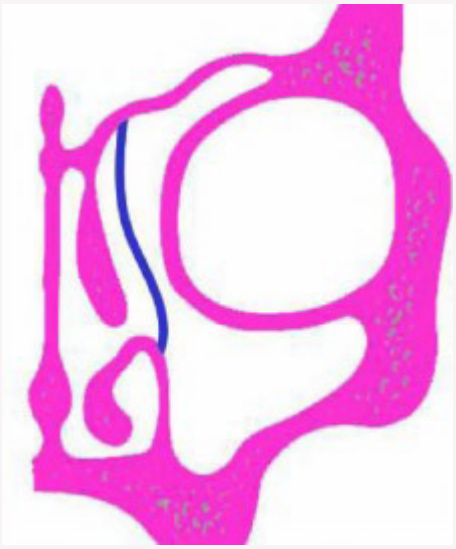


Image showing uncinate process attached to the skull base. Frontal sinus here drains into the superior end of ethmoidal infundibulum.

Image showing uncinate process getting attached to the superior - anterior portion of the middle turbinate. The frontal recess drains into the superior end of ethmoidal infundibulum.

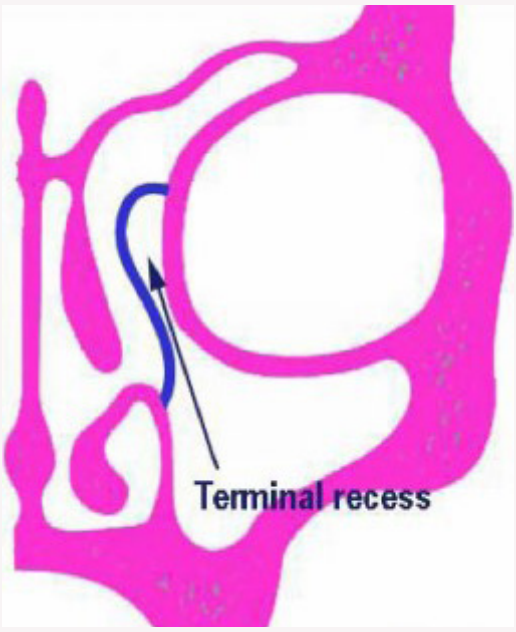


Image showing terminal recess

If the uncinate process gets attached to lamina papyracea the frontal recess opens directly into the superior aspect of middle meatus. The ethmoidal infundibulum ends directly into a terminal recess. Frontal sinus drainage can occur via ethmoidal infundibulum if the uncinate process doesn't get attached to the lamina papyracea.

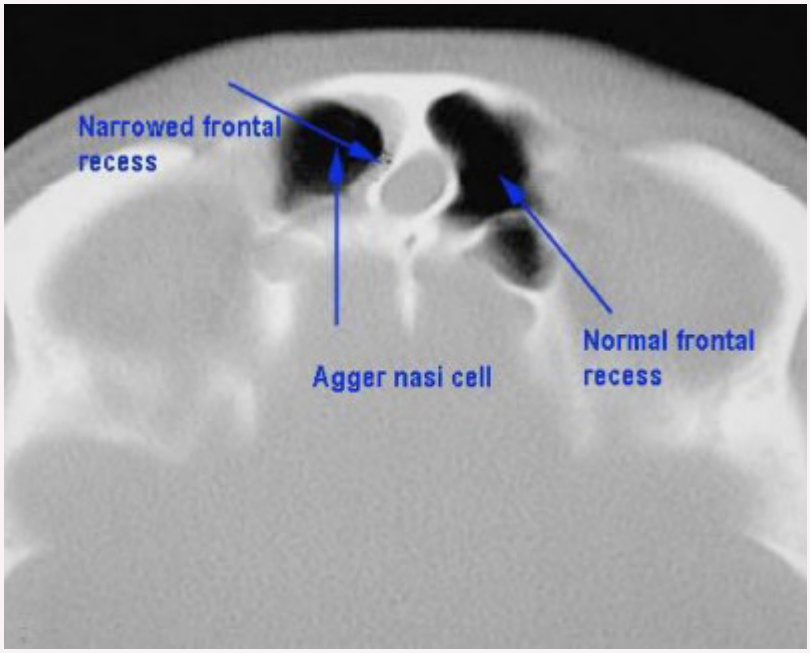


Image of Axial CT of nose and PNS showing large agger nasi cell narrowing the frontal recess area obstructing frontal drainage tract.

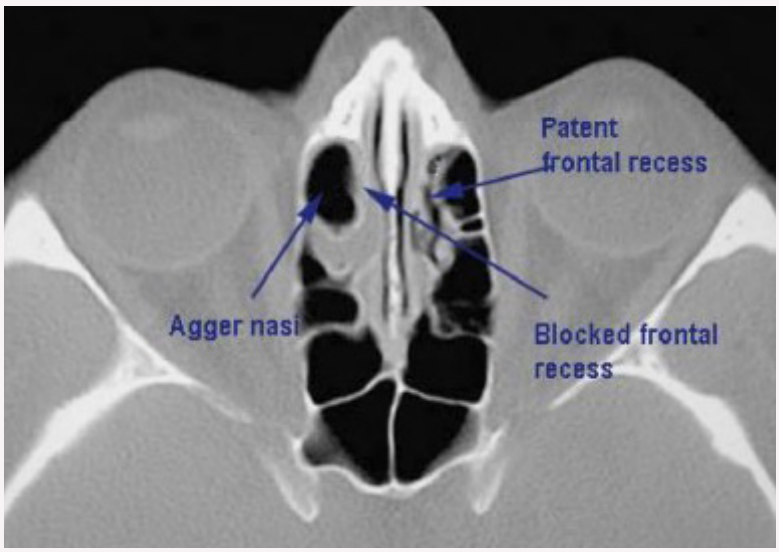


Image showing axial cut nose and sinuses with enlarged agger nasi cell causing obstruction to frontal recess area.

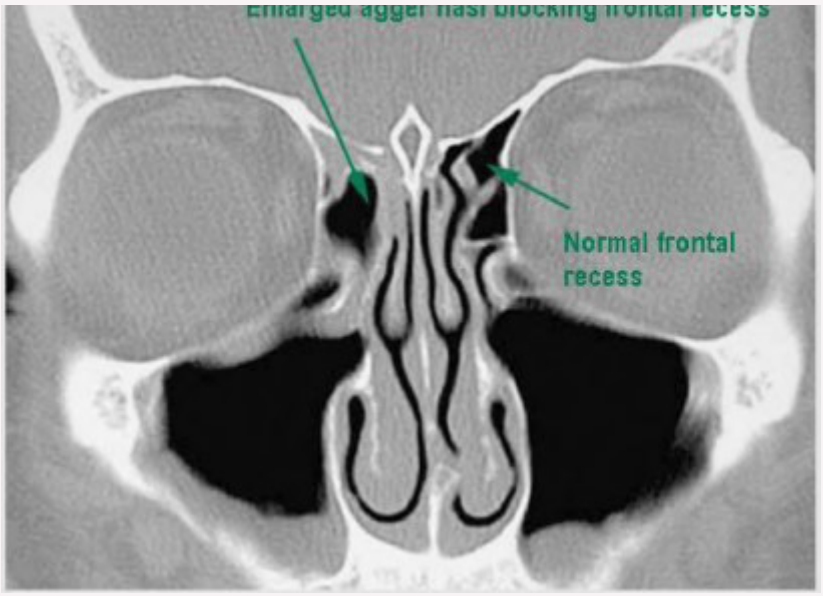


Image of large agger nasi cell causing obstruction to frontal sinus drainage on the right side (coronal CT of nose and sinuses).

Image showing uncinate process attached to skull base. The frontal recess is seen between the agger nasi and uncinate process (Coronal CT nose and sinuses).

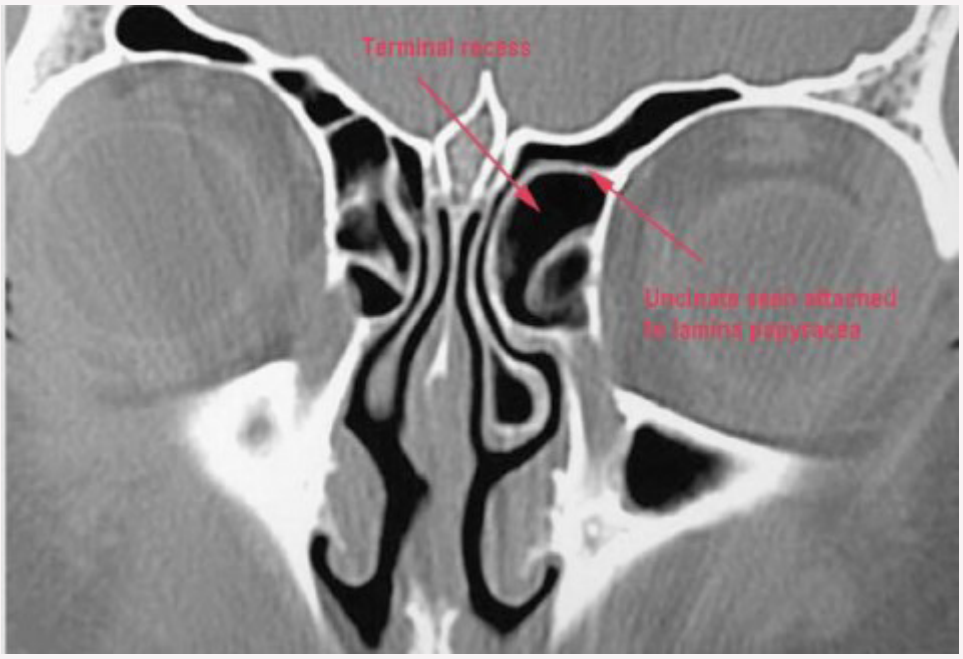
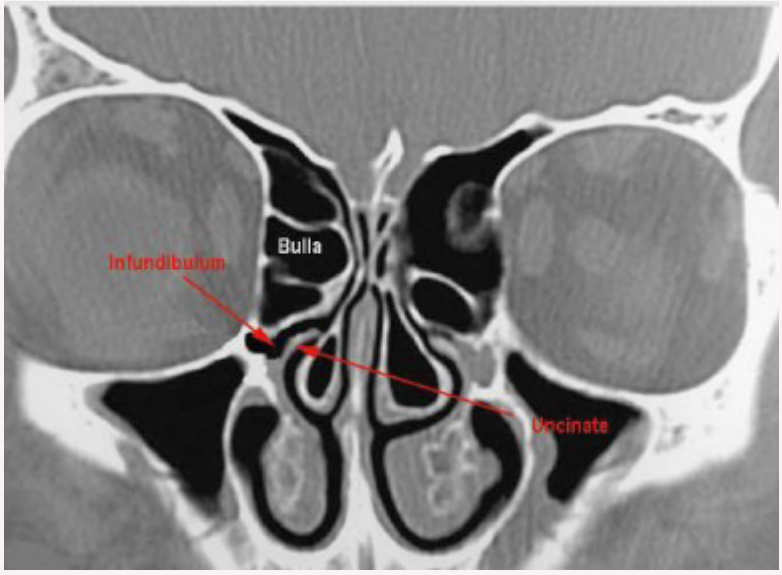


Image of Coronal CT scan showing uncinate process being attached to lamina papyracea. This causes terminal recess to form. Frontal sinus drains directly into middle meatus as shown in this figure.



This coronal CT scan shows the uncinate process being attached to the middle turbinate. Note the presence of infundibulum between the bulla and the uncinate process. Frontal sinus is seen opening into the infundibulum. Note also the fairly deep olfactory fossa.

Anatomic variants of frontal sinuses:

Detailed understanding of variations seen in the anatomy of frontal sinus will help the surgeon to avoid unnecessary complications during surgical procedures involving the frontal sinus and skull base.

Frontal cells: These are rare anatomic variants that involve ethmoidal pneumatization that impinge on the frontal recess area. These cells may also extend to involve the lumen of frontal ostium. According to Bent there are four types of frontal cells.

Bent's classification of frontal cells:

Type I frontal cells: This is a single frontal recess cell above the agger nasi.
Type II frontal cells: This is a tier of cells above agger nasi, projecting within the frontal recess
Type III frontal cell: This is a single and massive cell arising above the agger nasi. The pneumatization occurs in a cephalad direction in to the frontal sinus.
Type IV frontal cell: This is a single isolated cell within the frontal sinus. This cell is sometimes difficult to visualize due to its very thin walls.

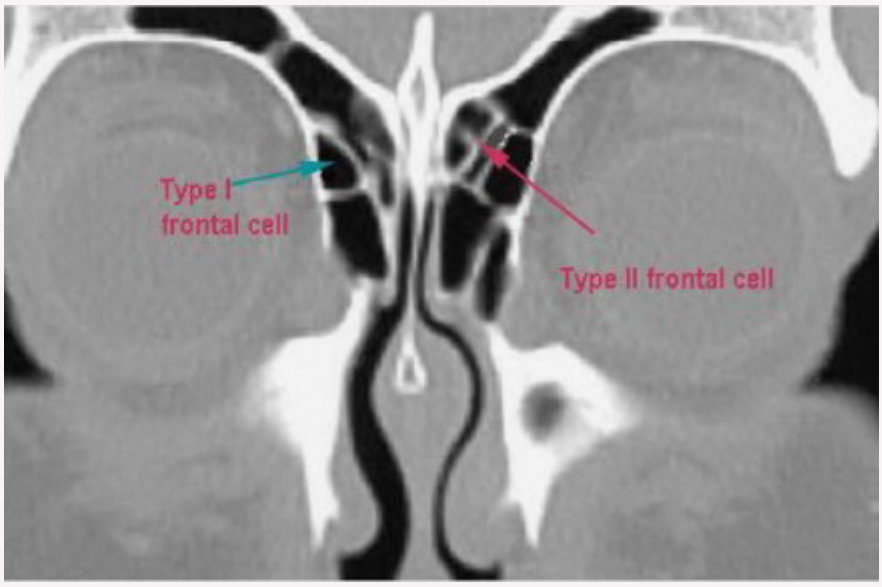


Image of coronal section of CT nose and sinuses showing type I frontal cell on the right side and type II frontal cell on the left.

Image showing type III frontal cell on the right side

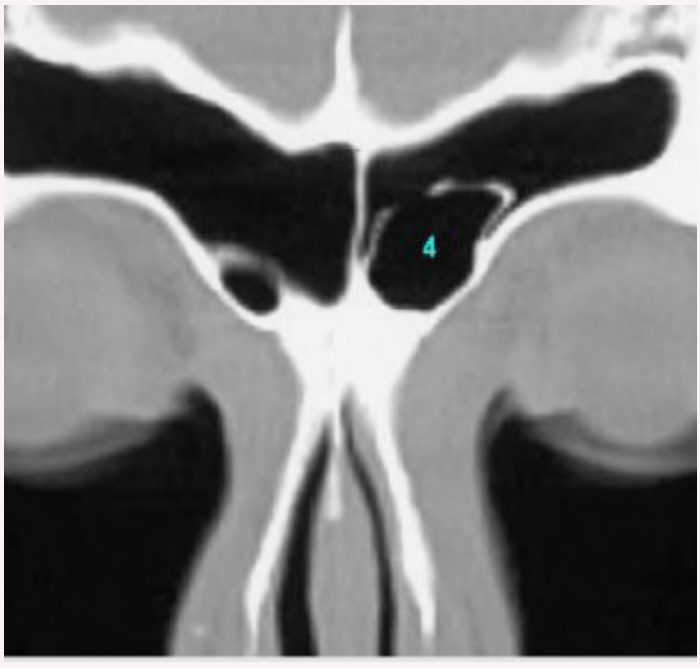


Image showing type IV frontal cell on the left side (4)

Supraorbital ethmoidal air cell:

These cells are caused by pneumatization of orbital plate of frontal bone posterior to the frontal recess and lateral to the frontal sinus. Sometimes these supraorbital air cells can reach up to the anterior margin of the orbital plate mimicking a frontal sinus.

Image of axial CT showing supraorbital cell (SOE)

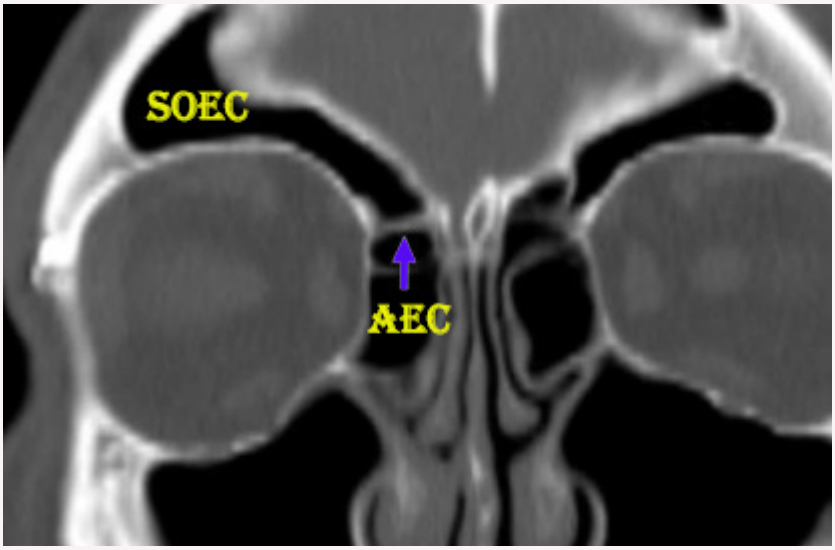


Image showing Coronal CT of nose and sinuses exhibiting supra orbital ethmoidal cell. The presence of this cell is associated with a high prevalence of anterior ethmoid artery coursing below the level of skull base. The artery is at a greater risk during surgeries involving this area. SOEC (supra orbital ethmoidal cell, AEC Anterior ethmoidal air cell).

Osteomeatal complex

Ostiomeatal complex:

This term is used by the surgeon to indicate the area bounded by the middle turbinate medially, the lamina papyracea laterally, and the basal lamella superiorly and posteriorly. The inferior and anterior borders of the osteomeatal complex are open. The contents of this space are the aggernasi, nasofrontal recess (frontal recess), infundibulum, bulla ethmoidalis and the anterior group of ethmoidal air cells.

This is in fact a narrow anatomical region consisting of :

1. Multiple bony structures (Middle turbinate, uncinate process, Bulla ethmoidalis)
2. Air spaces (Frontal recess, ethmoidal infundibulum, middle meatus)
3. Ostia of anterior ethmoidal, maxillary and frontal sinuses.

In this area, the mucosal surfaces are very close, sometimes even in contact causing secretions to accumulate. The cilia by their sweeping movements pushes the nasal secretions. If the mucosa lining this area becomes inflamed and swollen the mucociliary clearance is inhibited, eventually blocking the sinuses.

Some authors divide this osteomeatal complex into anterior and posterior.
The classic osteomeatal complex described already has been described as the anterior osteomeatal complex, while the space behind the basal lamella containing the posterior ethmoidal cells is referred to as the posterior ethmoidal complex, thus recognising the importance of basal lamella as an anatomical landmark to the posterior ethmoidal system. Hence the anterior and the posterior osteomeatal complex has separate drainage systems. So when the disease is limited to the anterior compartment of the osteomeatal complex, the ethmoid cells can be opened and diseased tissue removed as far as the basal lamella, leaving the basal lamella undisturbed minimising the risk during surgery.

Obstruction to this area can predispose to sinusitis.
Solken etal described 5 types of obstruction in Osteomeatal complex area.

1. Infundibular pattern:

Sinus disease is limited to infundibulum and maxillary sinus; fromtal and ethmoidal sinuses are spared. Secondary to swollen mucosa, polyps, Hallercells.

2. Osteomeatal unit pattern:

Middle meatus, anterior-middle ethmoidal air cells, maxillary and frontal sinuses are involved. Secondary to swollen mucosa, polyp, concha bullosa,septal deviation, nasal tumor.

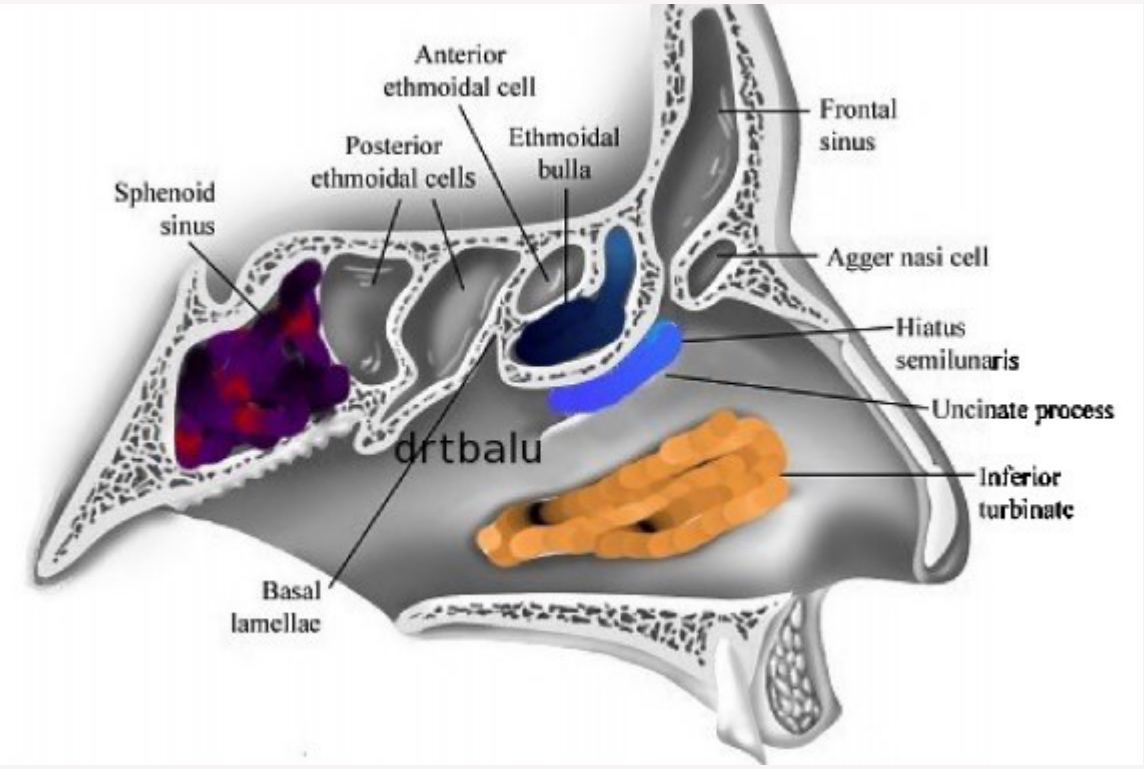


Image showing Oseomeatal complex

3. Sphenoethmoidal recess pattern: Sphenoid and posterior ethmoid air cells are involved.

4. Sinonasal polyp pattern: Polyps fill nasal cavity and sinuses bilaterally

5. Unclassifiable pattern/sporadic pattern: Secondary to retention cysts, mucoceles, post-op changes

Image showing coronal CT of nose and sinuses showing infundibular pattern of OMC obstruction.

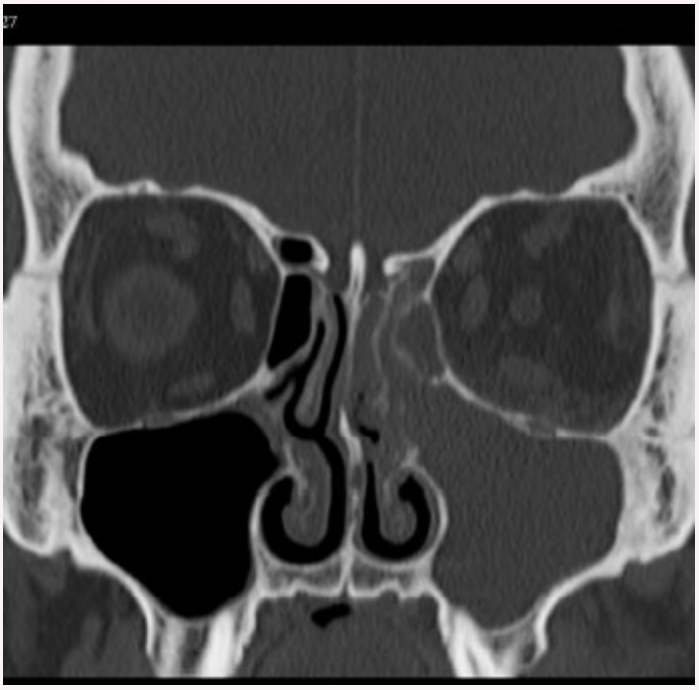


Image of coronal CT of nose and sinuses showing osteomeatal unit pattern of obstruction

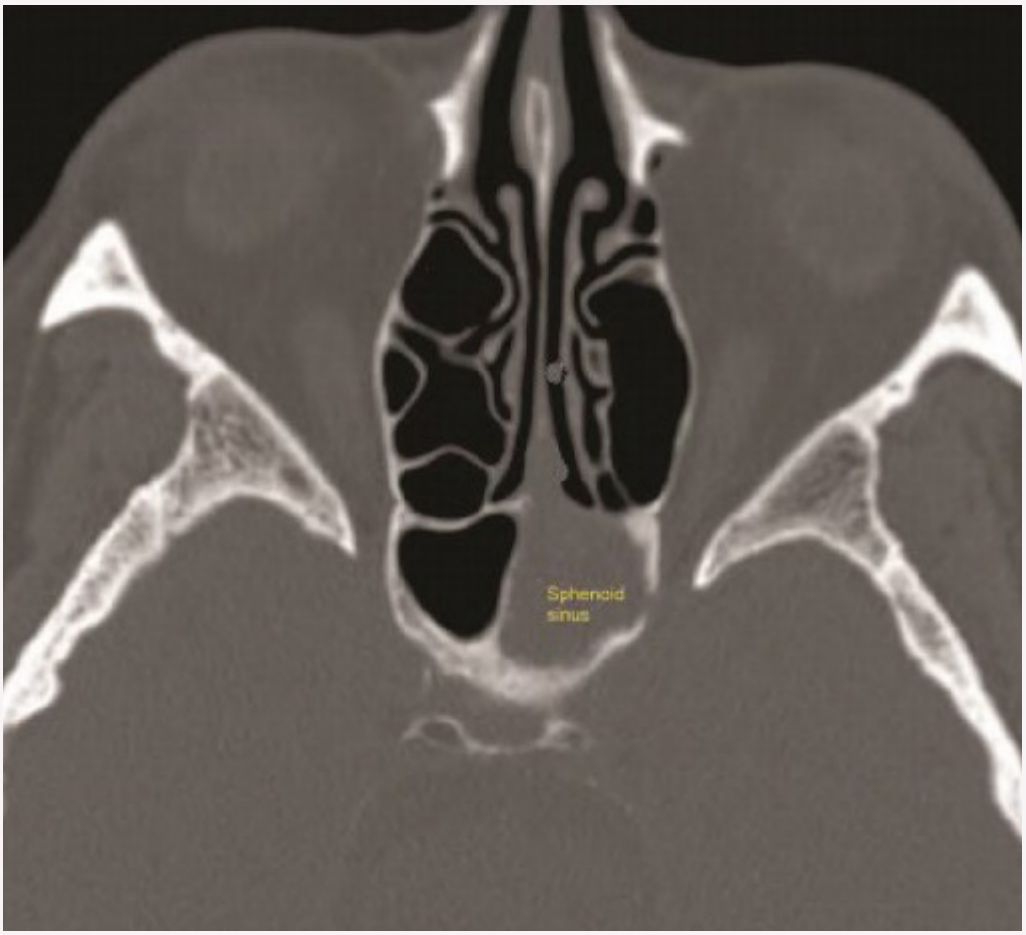


Image showing axial CT of nose and sinuses showing sphenoethmoidal pattern of obstruction

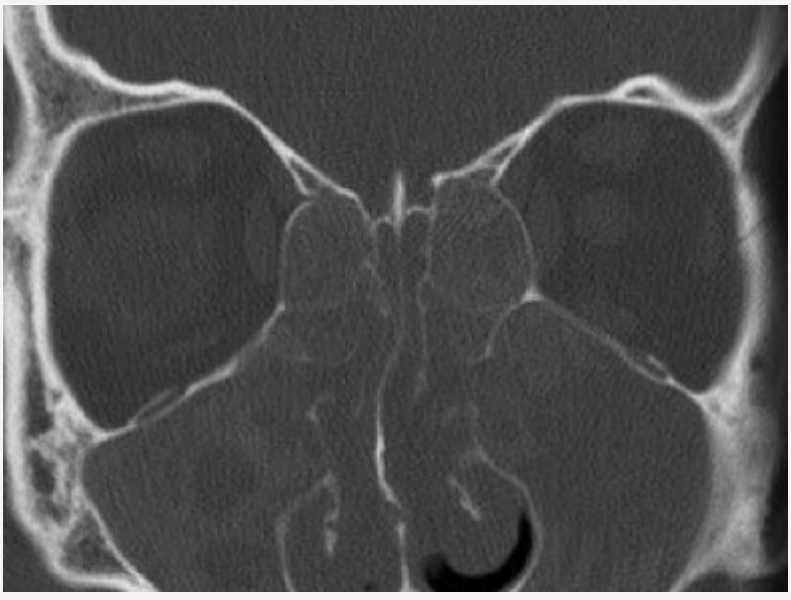


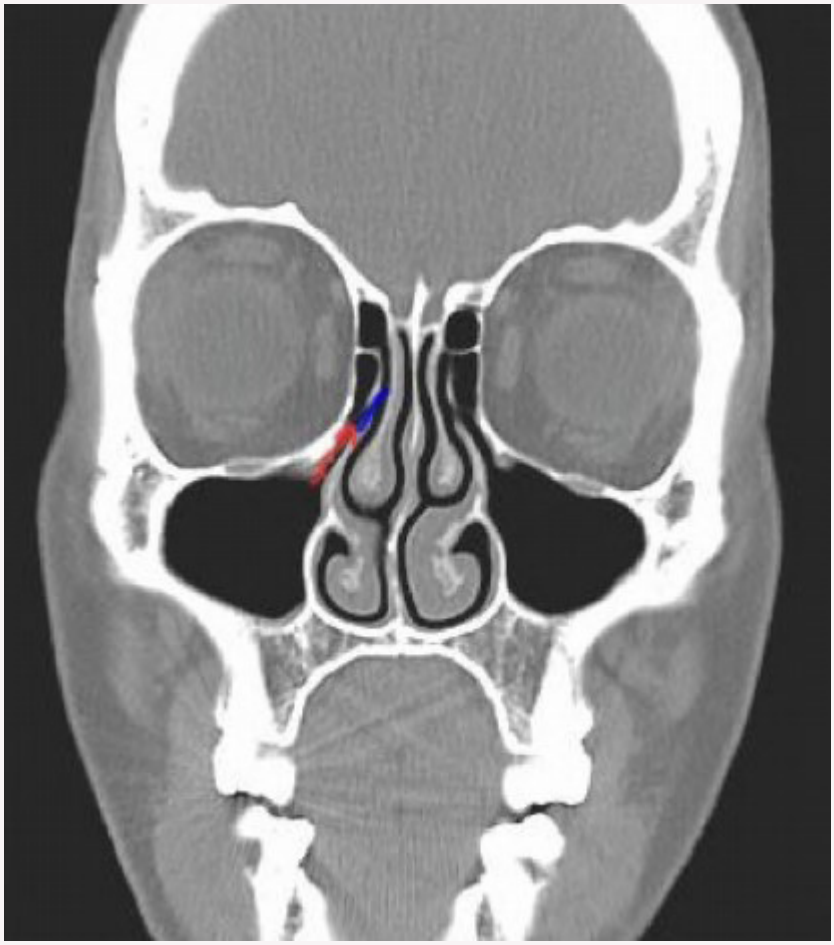
Image showing coronal CT of nose and sinuses showing sinonasal poypoidal pattern

Ethmoidal infundibulum:

This is a cleft like three dimensional space in the lateral wall of the nose. This space actually belongs to the anterior ethmoid. Boundaries of this space include:

Medial wall - Uncinate process and its mucosal covering
Lateral wall - Lamina papyracea of orbit (medial wall of orbit), frontal process of maxilla, rarely lacrimal bone.
Posterior wall - Anterior surface of bulla ethmoidalis
The anterior border of uncinate process fuses with frontal process of maxilla,this causes infundibulum to end blindly anteriorly in an acute angle. This causes infundibulum to appear like a "V" in horizontal sections (i.e. axial CT).

Hiatus semilunaris:
This is a two dimensional space between the anterior wall of ethmoid bulla and the free posterior margin of uncinate process.



Coronal CT nose and sinuses showing Ethmoidal infundibulum (red line) Hiatus semilu naris (blue line)

1

Hiatus semilunaris can be considered as a door through which one can reach the ethmoidal infundibulum.

Inflammatory lesions of nose and sinuses

Mucosal lining of nose and sinuses should be considered as a single entity because they form one continuous lining. Inflammation involving nasal mucosa can also affect the mucosal lining of paranasal sinuses, similarly vice versa is also possible. Hence the term rhinosinusitis would be apt. Inflammation involving mucosa of nose and sinuses could be caused by:

1. Allergic reaction
2. Viral infections
3. Bacterial infections
4. Fungal infections

Sinusitis can also be classified according to the duration of illness:
1. Acute sinusitis - Duration of illness is less than 3 weeks
2. Sub acute sinusitis - Duration of illness ranging between 3-6 weeks
3. Recurrent sinusitis - Recurrent sinusitis with disease free periods in between attacks.
4. Chronic sinusitis - Duration of illness is more than 6 weeks

Sinusitis can also be classified according to the sinus involved:

1. Frontal sinusitis
2. Ethmoidal sinusitis
3. Maxillary sinusitis
4. Sphenoidal sinusitis

The time frame involved in classification of sinusitis is not absolute. In acute infections mucosa heals without residual effects. In chronic infections there will be some amount of residual effect on the mucosa.

Mucosal drainage system of paranasal sinuses are entirely dependent on the mucociliary clearance mechanism. During infections mucociliary clearance mechanism is affected leading on to stasis within the sinus

Drainage from sinuses has to pass through narrow channels:

1. Frontoethmoidal recess
2. Infundibulum
3. Sphenoethmoidal recess

In anatomical terms these areas are known as tight spots which can easily be obstructed due to mucosal oedema.

Tight spot components around frontal recess area include:

1. Frontal sinus
2. Frontal cells
3. Agger nasi
4. Frontal recess
5. Nasofrontal beak
6. Middle meatus

Tight spot anatomy in the infundibular area:

1. Ethmoidal bulla
2. Uncinate process
3. Infundibulum
4. Maxillary sinus
5. Natural ostium of maxillary sinus
6. Middle turbinate
7. Middle meatus
8. Hiatus semilunaris
9. Retrobulbar recess
10. Basal lamella

Tight spot anatomy in the sphenoid ethmoidal recess area:

1. Superior turbinate

2. Posterior ethmoid sinus

3. Sphenoid sinus ostium

4. Sphenoid sinus

5. Optic nerve

6. Carotid canal

7. Foramen rotundum

8. Vidian canal

These are mucous membrane lined pathways which commonly become ob
structed due to mucosal oedema. In acute phases of infections mucosal oedema to these critical drainage area along with temporary disruption of mucociliary clearance mechanism are the major pathophysiologic mechanismscausing sinusitis.

Inflammatory disorders of sinuses can be effectively evaluated by CT imagingof the area. It is not routinely indicated unless there is a suspicion of involvement of areas like orbit and adjacent soft tissue.

Acute sinusitis:

Acute bacterial sinusitis is caused due to bacterial infection in an obstructed sinus. Obstruction of sinus drainage channel is caused due to opposition of contiguous mucosal surfaces due to oedema caused by viral infection. Viral infections involving mucosal lining of nasal cavity is known to predispose to
bacterial infection of sinuses. Obstruction to sinus cavity causes changes in the oxygen tension within it predisposing to superadded bacterial infection.

Acute sinusitis usually involve a single sinus, ethmoidal sinus being the most commonly involved sinus. These patients have increased risk of intracranial complications with the involvement of frontal, ethmoid and sphenoid sinuses. Orbital complications are also common. Acute viral infections rarely cause acute sinusitis.

Clinically the point of transition from viral sinusitis to acute bacterial sinusitis can be identified when clear secretions formed by viral infections become yellow. Yellowish nasal secretion indicate acute bacterial purulent sinusitis.

When inflamed mucosa is imaged (in acute sinus infections) it is seen as enhancing lesion due to the presence of varying amounts of water content in them. Pain occurs in acute sinus infections only when the ostium is blocked and the draining sinus is filled with secretions.

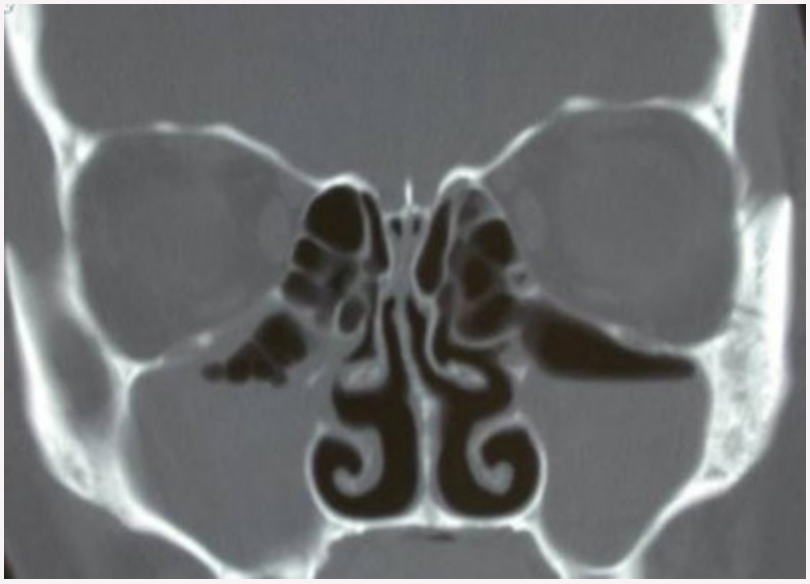
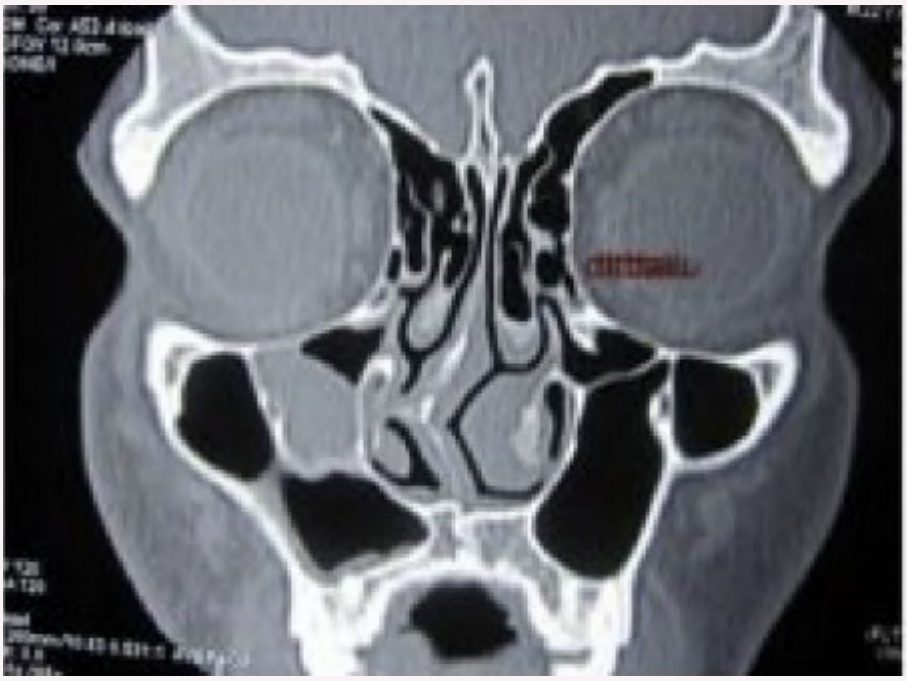


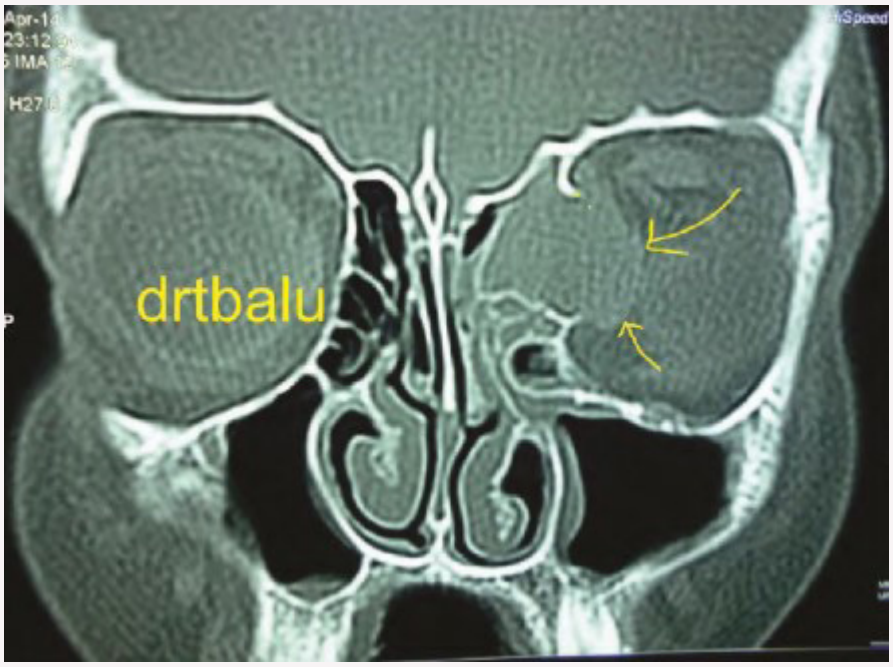
Image showing air fluid levels in both maxillary sinuses. This is the classic feature of acute infections involving maxillary sinus.

Image showing air fluid levels (frothy appearance) in left maxillary sinus with evidence of infundibular obstruction. Feature suggestive of acute maxillary sinusitis.

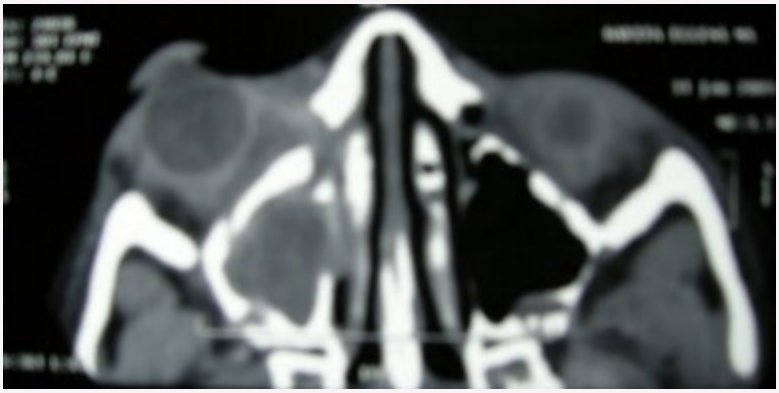


Coronal CT image of paranasal sinuses showing acute infection involving Haller cell. Note the fluid level inside the Haller cell cavity.

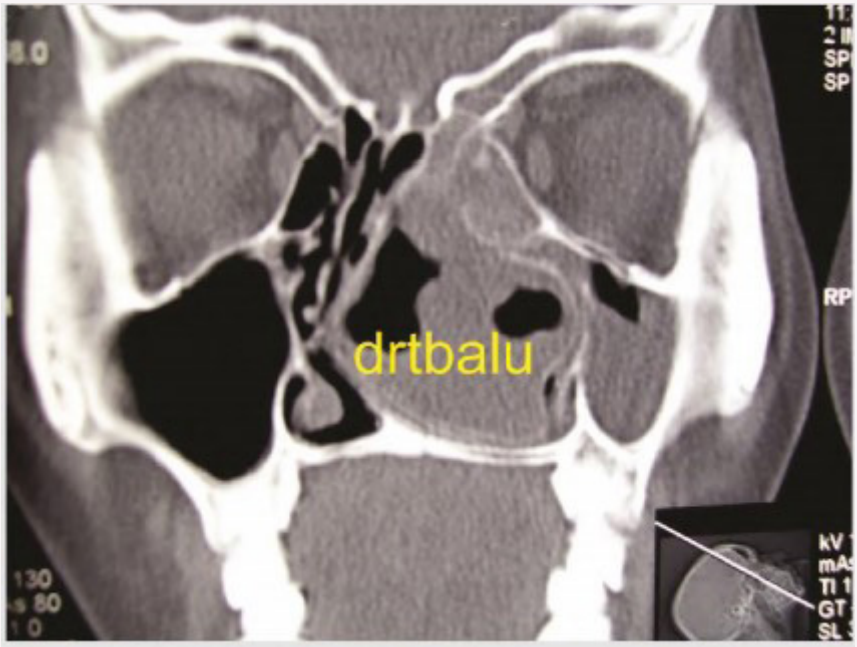
Acute bacterial sinusitis is more likely to spread to orbit than intracranially. The thin lamina papyracea that separates orbital contents from ethmoidal sinuses can easily be breached by infections involving ethmoidal sinuses. In addition to this the anterior and posterior ethmoidal veins are devoid of valves allowing spread of infections from ethmoidal sinuses to orbit.



Coronal CT of nose and sinuses showing acute ethmoiditis involving orbit



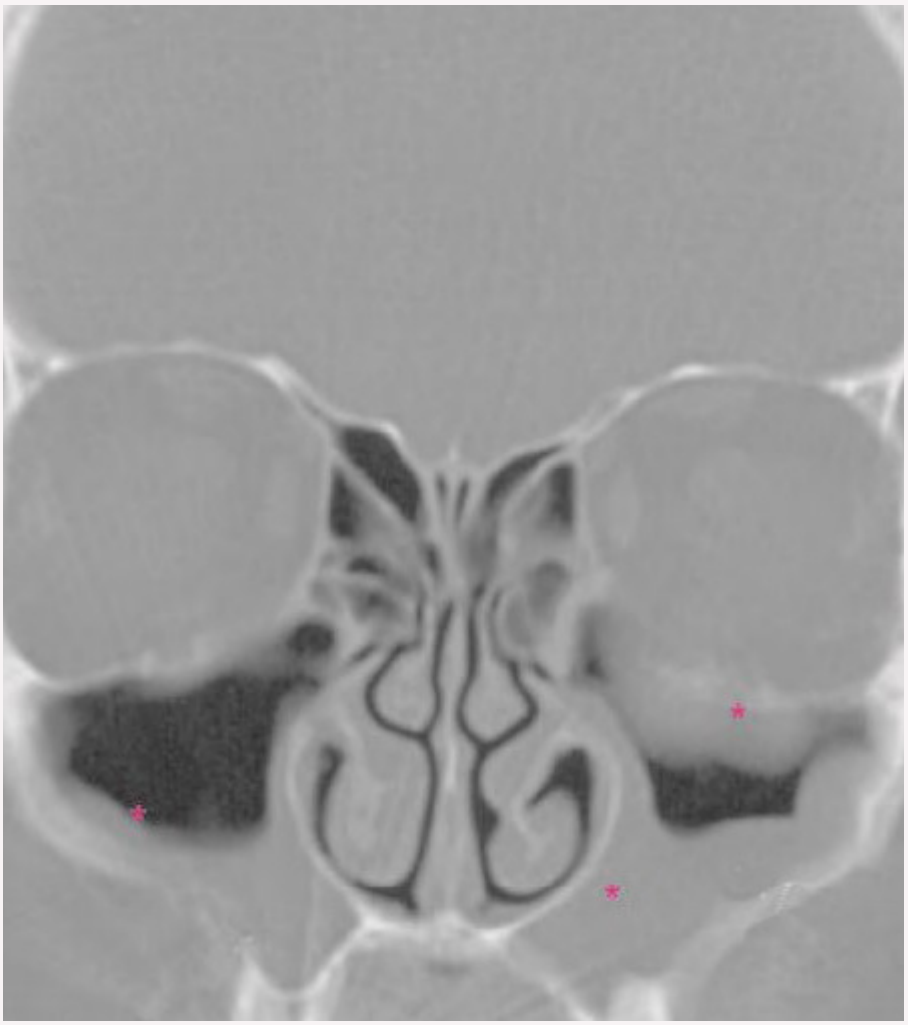
Axial showing acute ethmoidal and maxillary sinusitis with orbital cellulitis



Coronal CT nose and sinuses showing huge infected concha bullosa

Concha bullosa is usually associated with septal deviation to the opposite side. Studies have revealed that septal deviation does not cause concha bullosa, but it augments middle turbinate pneumatization if present. Presence of infection in a huge concha bullosa of middle turbinate also causes secondary maxillary sinusitis on the same side. In this scenario endoscopic resec
tion of lateral wall of concha bullosa would be helpful.

Contiguous spread of infection from ethmoid sinus to involve the adjacent lacrimal drainage system causes symptoms similar to that of acute dacryocystitis. Hence before embarking on the management of dacryocystitis it is imperative to perform CT imaging of sinuses. Acute bacterial sinusitis is caused by obstruction to normal drainage channels of sinuses. Hence acute sinusitis occurs as a sinus by sinus event rather than a generalized open.
Even in the presence of pansinusitis due to acute bacterial infections it could be appreciated that one or more of the sinuses are more severely affected than the rest. Asymmetry is the classic feature of acute bacterial sinusitis. In the case of allergic sinusitis there is more or less uniform involvement of all the sinuses as pathophysiology in this condition is more generalized in nature.

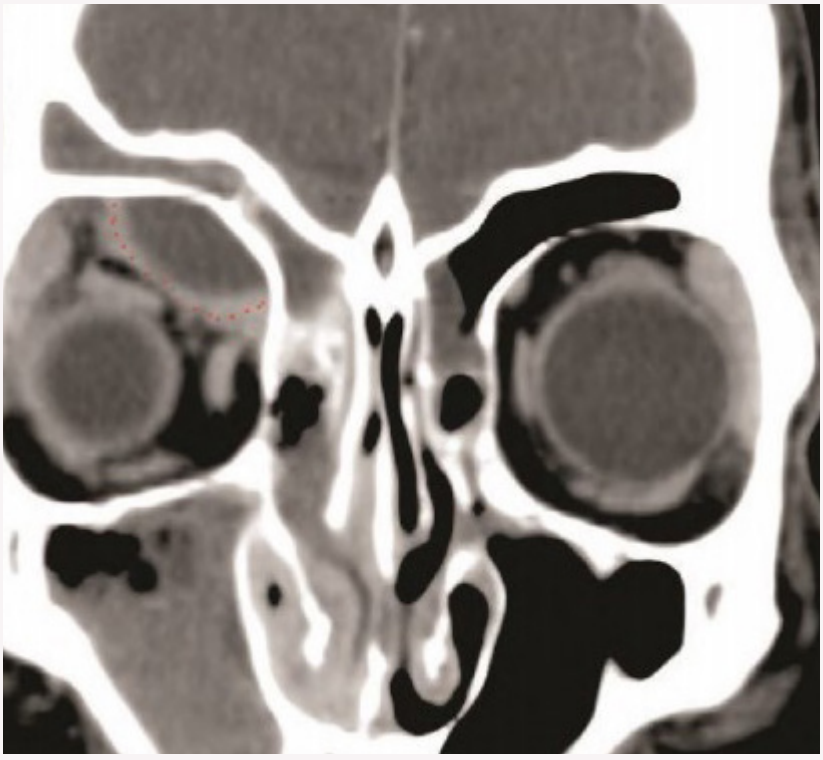


Coronal CT image of nose and sinuses showing evidence of allergic sinusitis. Note the coconut kernel like thickening of maxillary sinus mucosa

Air fluid levels:

Air fluid levels are commonly seen in maxillary sinuses due to acute obstruc tion of maxillary sinus ostium due to acute bacterial sinusitis. This is commonly seen in about 25% of patients with acute sinus infections. During the era of antral wash, residual fluid level within maxillary sinus could be visualized even up to 4 days following the wash. This has been attributed to the presence of saline used for lavage within the sinus. If patient gives history of antral lavage then CT imaging should be ideally delayed up to a week after lavage. A persistent fluid level even after a week following antral lavage indicates persistent obstruction to sinus drainage.

Image showing axial CT image of nose and sinuses showing fluid level in the maxillary sinus cavity



Coronal CT nose and sinuses showing right maxillary sinusitis with right subperiosteal abscess

Nasogastric tube placement and prolonged supine positioning can cause air fluid levels to occur in maxillary sinuses. Naso gastric tube interferes with maxillary sinus discharge due to nasal mucosal oedema. Maxillary sinus drainage block starts within the first 24 hours of insertion of nasogastric tube.

Significance of air fluid level varies according to the sinus involved. If air fluid level is present in frontal sinuses it invariably means acute bacterial sinusitis.

Intracranial complications occur within 48 hours of frontal sinus infection. If symptoms don't show improvement or if imaging shows evidence of air fluid level even after 48 hours after treatment then trephining of the sinus should be considered.

Air fluid level in ethmoid sinuses is a rare occurrence. Even if present it should be considered as a Mucopyocele due to rupture of ethmoidal mucocele with partial drainage into the nasal cavity.

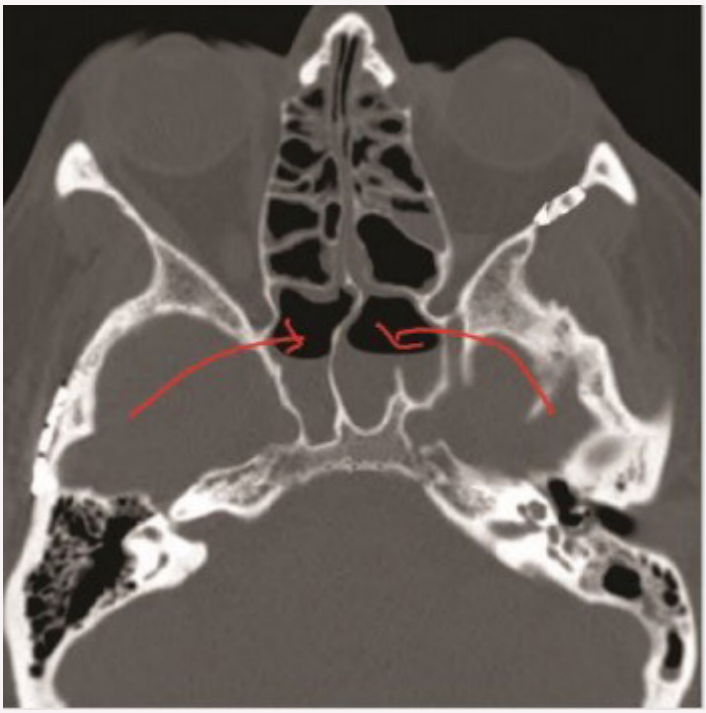
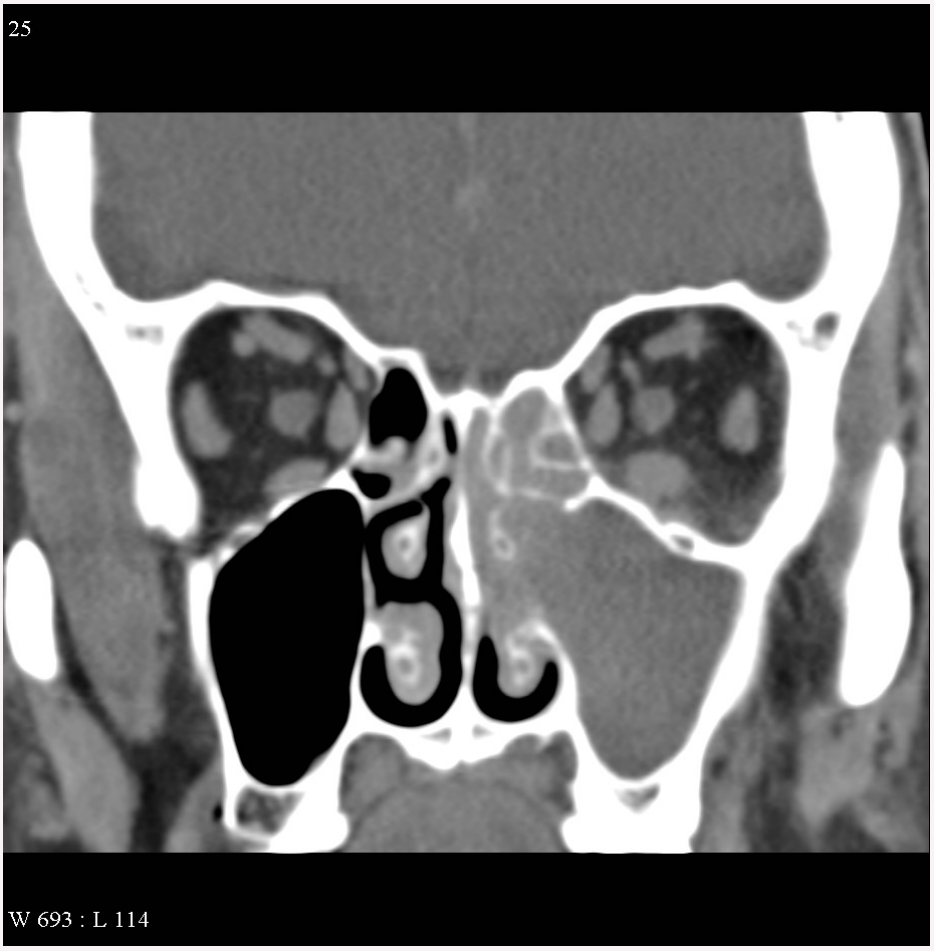


Image showing axial CT of nose and sinuses with fluid level in ethmoid and sphenoid sinuses.

Presence of air fluid level in sphenoid sinus indicates the presence of acute sinusitis / nasal obstruction. In patients with history of head injury, presence of air fluid level in sphenoid sinus indicates presence of hemorrhage / CSF leak.



Coronal CT of nose and sinuses showing haziness of left maxillary sinus with evidence of left osteomeatal complex obstruction. Note the lack of periosteal thickening which is a feature of chronic sinusitis.

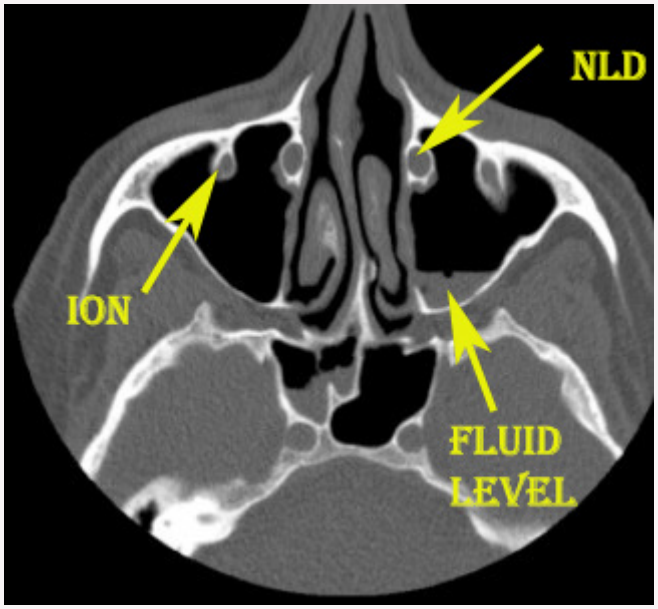


Image showing axial CT of nose and sinuses showing fluid level in the maxillary sinus

NLD - Nasolacrimal du ct

ION - Infraorbital nerve

Image showing axial CT of nose and sinuses showing fluid level in ethmoidal sinuses on both sides.

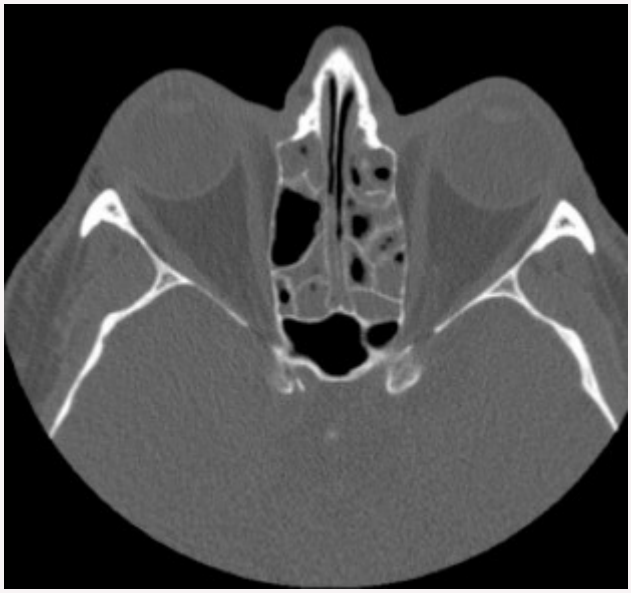


Image showing fluid level in ethmoidal sinuses on both sides

Chronic sinusitis:

This is a common and more prevalent illness. This term indicates presence of inflammatory process in the mucosal lining of paranasal sinuses for 12 weeks or longer. Chronic sinusitis is always associated with concurrent nasal airway inflammation. Since chronic sinusitis is always preceded by rhinitis the term chronic rhinosinusitis would be more appropriate. Majority of chronic sinusitis are caused by continuation of unresolved acute sinusitis.

Sometimes chronic sinusitis can occur in the absence of acute sinusitis. In 1996 American Academy of Otolaryngology - Head and neck surgery Multidisciplinary Task force came out with adult rhinosinusitis diagnostic criteria which included:

1. Facial pain
2. Nasal obstruction
3. Nasal discharge / Purulence
4. Hyposmia
5. Anosmia
6. Fever

In 2003 this criteria was widened to include radiological evidence also. Chronic sinusitis may manifest as one of the three following syndromes:

1. Chronic rhinosinusitis without nasal polypi
2. Chronic rhinosinusitis with nasal polypi

3. Allergic fungal sinusitis

This classification is significant because of the varying treatment methodologies followed to treat them.

Pathophysiology of chronic sinusitis:

Stasis of secretions within the sinus cavities triggered by:
1. Mechanical obstruction at the level of Osteomeatal complex due to prevailing anatomical anomalies.
2. Mucosal oedema due to various causes

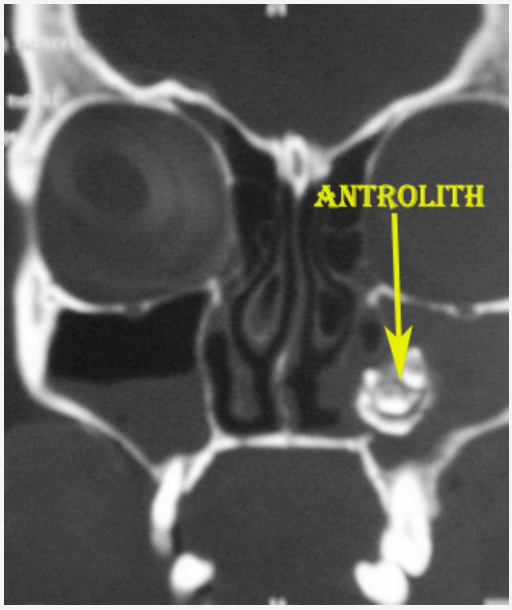
Current concept:
Currently chronic rhinosinusitis is considered to be a multifactorial disease due to:

1. Persistent infection (Including osteitis and presence of biofilm)
2. Allergy and other immunological disorders
3. Intrinsic factors of upper airway
4. Super antigens
5. Colonizing fungi that induce and sustain eosinophilic inflammation of sinus mucosa
6. Aspirin sensitivity

Image of Coronal CT showing chronic sinusitis with nasal polyposis (Note turbinates cannot be differentiated from nasal polypi unless window setting is changed to bone window).

Coronal CT image of nose and sinuses bone window setting. Here turbinates and polypi can clearly be differentiated.

Management of chronic rhinosinusitis should be based on the causative factors which include:
Ostial blockage
Delayed recovery of mucociliary function
Mucous recirculation and presence of associated osteitis
Microbial factors causing persistence of infection



Coronal scan nose and sinuses showing antrolith in left maxillary sinus

A charactersitic feature on CT nose and sinuses of patients with chronic infections is the presence of sclerotic thickened bone (hyperostosis) involving sinus wall from prolonged mucoperiosteal reaction. Intrasinus calcification could also be present.

There are five main patterns of chronic inflammatory disease that classify the disease into distinct anatomical/pathological groups and are dependent on the drainage pathways affected. This classificatio helps the surgeon to select the type of surgery needed.

Ostiomeatal complex pattern - Maxillary sinus, ethmoid air ells, and frontal sinuses are affected due to obstruction of the ostiomeatal complex.

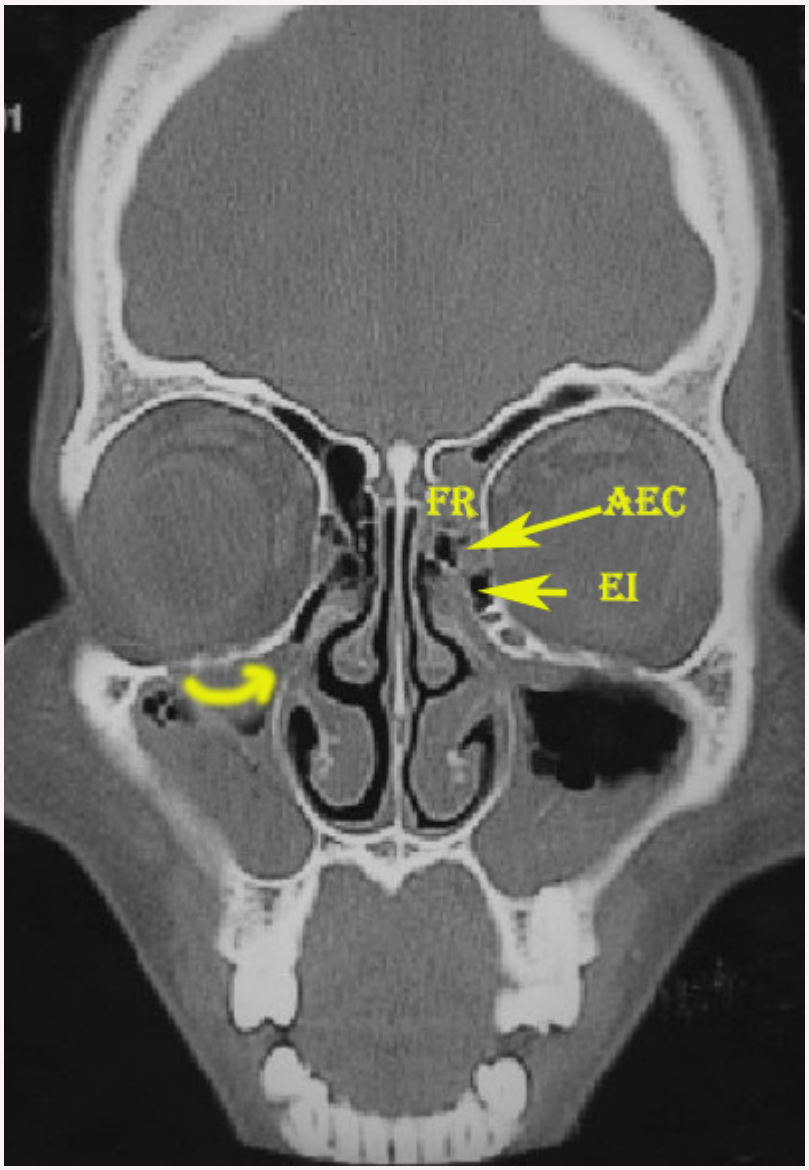
Infundibular pattern - Isolated obstruction to the ethmoid infundibulum / or maxillary sinus ostium.

Sphenoethmoidal recess pattern - Inflammatory changes in the sphenoethmoidal recess obstruct the sphenoid sinus in isolation or in conjunction with posterior ethmoid air cells.

Sinonasal polyposis pattern - Extensive polyposis could be seen occupying the nasal cavity and paranasal sinuses.

Sporadic pattern - No clear pattern can be identified with random mucosal thickening, and polypi.

Image showing axial cut with mucosal thickening in both maxillary sinuses with periosteal thickening indicating chronic sinusitis



Coronal CT nose and sinuses showing inflammation involving left osteomeatal unit.

FR - Frontal recess obstruction

AEC - Anterior ethmoid cells

EI - Ethmoid infundibulum

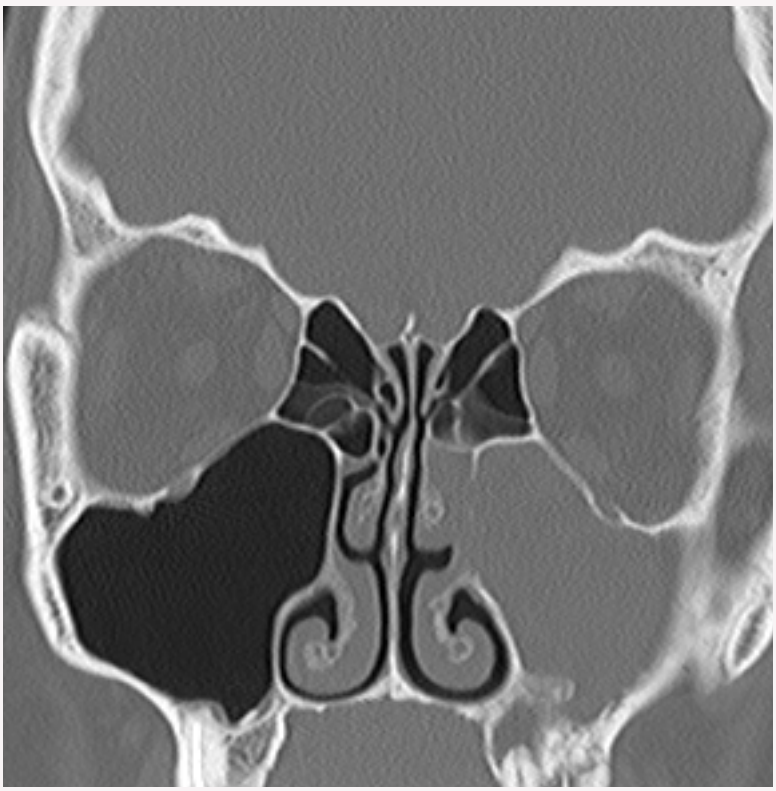
Curved arrow - Maxillary sinus ostium

Odontogenic sinusitis:

This condition is inflammation of maxillary sinus secondary to dental pathology or dental procedures. This condition accounts for nearly 10% of all cases of chronic maxillary sinusitis. It is the most common cause of unilateral maxillary sinusitis.

Chronic sinusitis is a clinical diagnosis that relies on the presence of signs and symptoms such as facial pain/pressure/fullness, mucopurulent nasal discharge, nasal congestion/obstruction, and reduction in the sense of smell. In order to establish a diagnosis of chronic sinusitis, these symptoms should be present for longer than 12 weeks despite attempts at medical treatment.

Odontogenic sinusitis results from spread of infection / inflammation from the teeth to the maxillary sinus via perforation of the sinus floor and disruption of the Schneiderian membrane.



Coronal CT nose and sinuses showing odontogenic abscess Left maxillary sinus with evidence of dental root destruction

CT findings:

Common finding that supports a diagnosis of odontogenic sinusitis is mucosal thickening in the inferior maxillary sinus (>2 mm is abnormal, >10 mm is marked / severe). Unilateral sinus opacification should raise the possibility of an odontogenic sinusitis.

Multiplanar evaluation of the maxillary molars and premolars and surrounding bone should be undertaken to identify a source such as periapical lucency, periodontal bone loss, oroantral fistula, and exogenous dental reconstructive/restorative material.

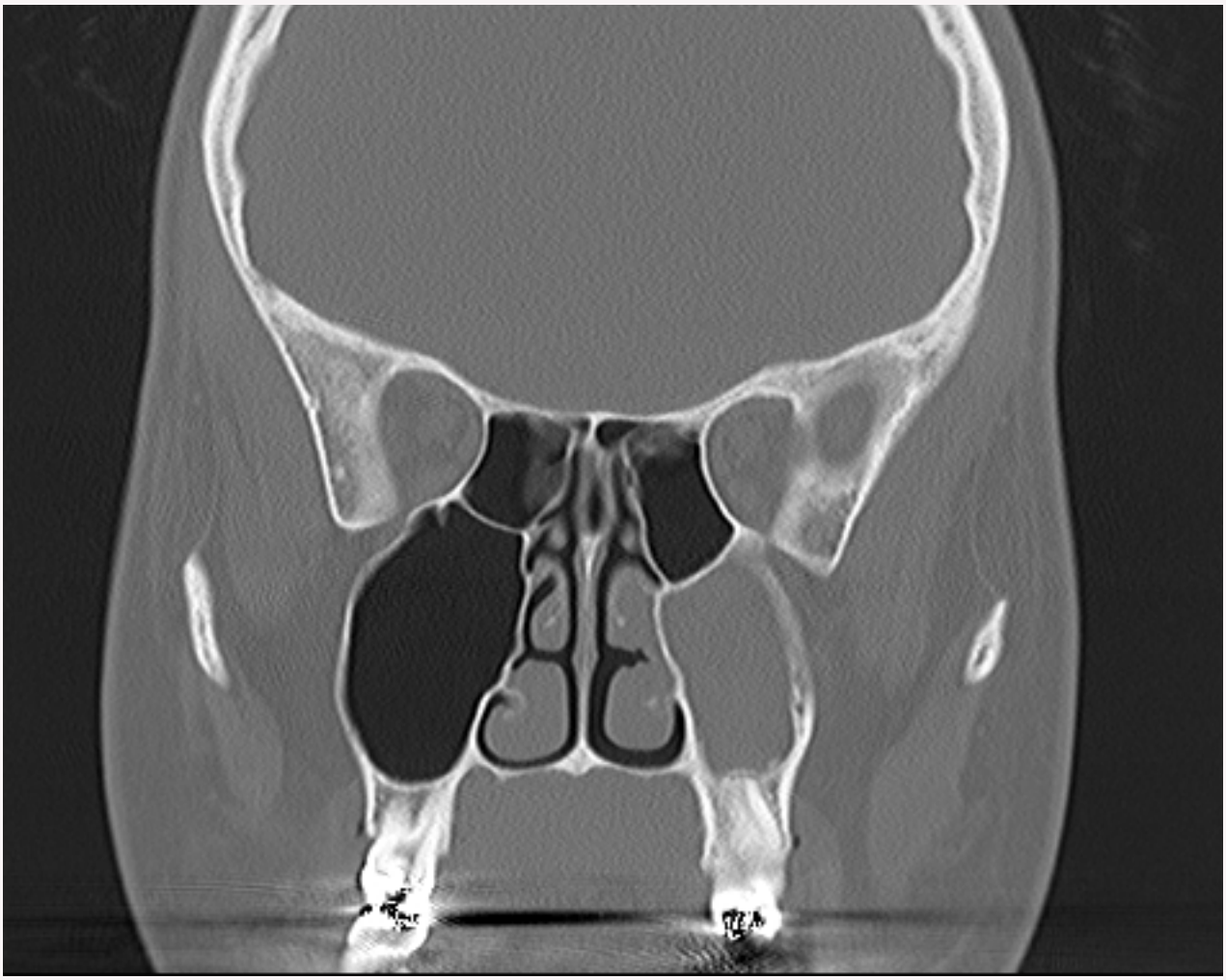


Image showiing left maxillary sinus opacity with evidence of dental root infection on that side. This is suggestive of odontogenic maxillary sinusitis

Mucoceles:

These are gradually expanding lesion involving paranasal sinuses. This is caused due to obstruction to the normal drainage channels of paranasal sinuses leading on to pent up secretions within it. These patients classically don't present with symptoms pertaining to nose and sinuses but with ophthalogical signs and symptoms. They invariably present to the ophthalmologist before finding their way to an otolaryngologist.

Definition:

A mucocele is defined as mucous filled epithelium lined sac. Mucoceles commonly involve ethmoidal and frontal sinuses. Mucoceles are commonly caused due to obstruction to drainage channel of paranasal sinuses. These expansile cystic masses are sometimes filled with mucopurulent secretions.

Sometimes associated bone destruction is also evident. Mucoceles are rather common in frontal sinuses. Next comes the ethmoidal sinuses. Isolated mucoceles involving ethmoidal sinuses are rather rare. They always occur in combination with frontal / sphenoid mucoceles.

Etiopathogenesis:

Mucoceles have been postulated to form due to obstruction of sinus ostia following chronic infections/allergic reactions involving paranasal sinuses. Previous trauma / surgery can also cause obstruction to sinus outflow channels causing formation of mucoceles. Ethmoidal mucoceles if present in isolation could be caused by endoscopic ethmoidectomy. Some studies have re ported occurrence of isolated ethmoidal mucoceles even 10 years after surgery. Paranasal sinuses continues to expand slowly owing to pent up mucous secretions. These mucoceles are lined by dilated ciliated columnar epithelium which secrete mucous causing expansion of the cyst. Continuing expansion of this cyst puts pressure on the bony walls of paranasal sinuses, causing bony erosion and remodeling.

Unchecked extension of sinus cavity can cause extension of mucocele into orbit, nasopharynx and cranial cavity7. In addition to pressure changes inflammatory mediators like prostaglandins, interleukins and tumor necrosis factor present within mucoceles also contribute to their expansion capability.

Three main theories of pathogenesis of mucocele formation has been postulated:

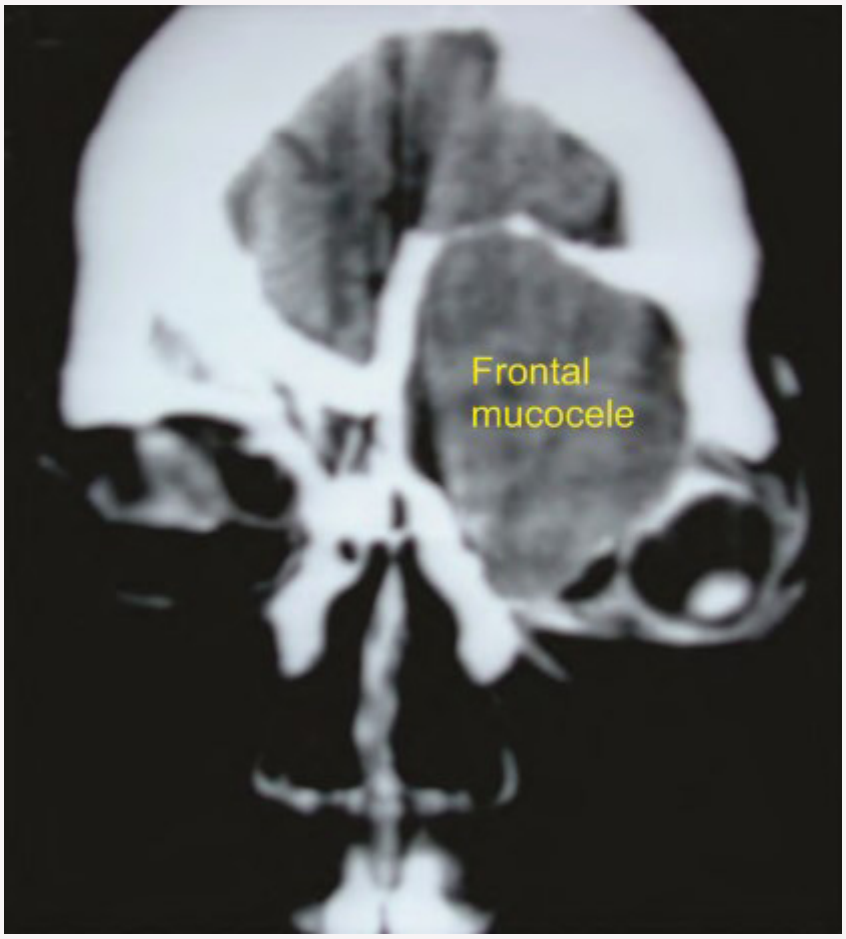
1. Pressure erosion
2. Cystic degeneration of glandular tissue
3. Active bone resorption and regeneration

Sites involved by mucoceles include:

1. Anterior ethmoid
2. Frontal
3. Maxilla

4. Posterior ethmoid
5. Sphenoid

About 60% of paranasal sinus mucoceles are present in the frontoethmoidal region.



Coronal CT nose and sinuses showing expansile lesion involving the frontal sinus pushing the orbit inferolaterally. The lesion could be seen extending to the anterior skull base.

Role of imaging in mucoceles:

Mucoceles are best imaged using a combination of CT and MRI scans. CT scans helps to assess bony changes while MRI scans assess extensions into orbit/cranium with great degree of accuracy.

CT scan features:

1. Complete Opacification of involved sinus
2. Expansion and thinning of involved sinus margins
3. Areas of complete bone resorption with resultant extension into adjacent areas like orbit and cranium
4. Contrast CT shows peripheral enhancement

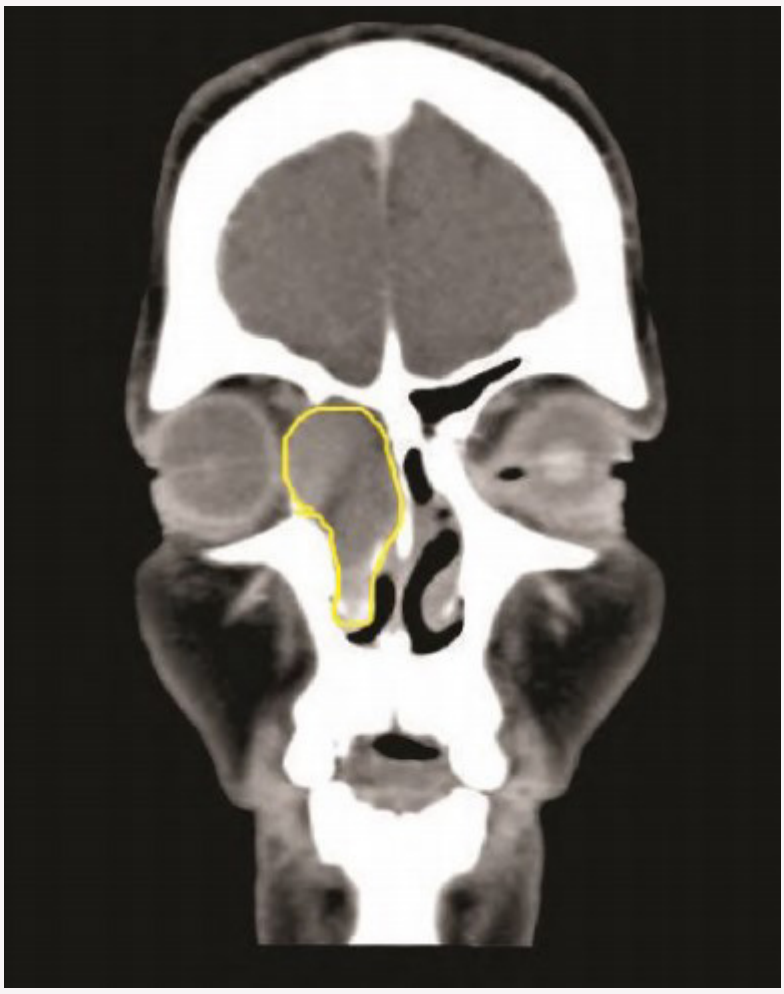
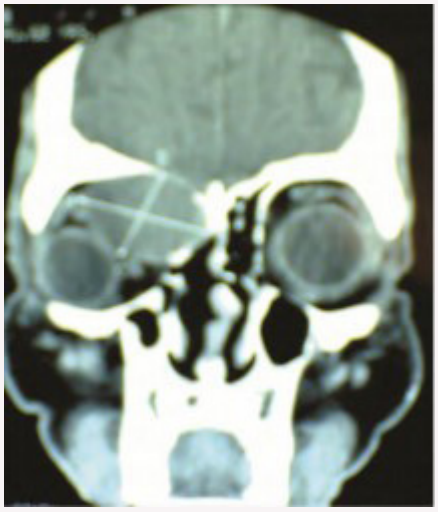


Image showing coronal CT of nose and sinuses revealing ethmoidal mucocele right side pushing the orbit laterally

Coronal CT of nose and sinuses showing mucocele involving right maxillary sinus with erosion of inferior orbital wall



Coronal CT of nose and sinuses showing frontal mucocele right side pushing the orbit laterally and downwards

Axial CT of nose and sinuses showing sphenoidal mucocele

Note: Sphenoidal mucoceles can present with vision disturbances.

Classification of frontal mucocele:

Frontal mucoceles have been classified into 5 types depending on its extent.

Type I: In this type the mucocele is limited to the frontal sinus only with or without orbital extension.
Type II: Here the mucocele is found involving the frontal and ethmoidal sinuses with or without orbital extension.
Type IIIa: In this type the mucocele erodes the posterior wall of the frontal sinus with minimal or no intracranial involvement.
Type IIIb: In this type the mucocele erodes the posterior wall with major intracranial extension.
Type IV: In this type the mucocele erodes the anterior wall of the frontal sinus.

Type Va: In this type there is erosion of both anterior and posterior walls of frontal sinus without or minimal intracranial extension.
Type Vb: In this type there is erosion of both anterior and posterior walls of frontal sinus with a major intracranial extension

Axial CT showing frontal mucocele type I

Coronal CT of nose and sinuses showing localized frontal sinus mucocele (Type I)

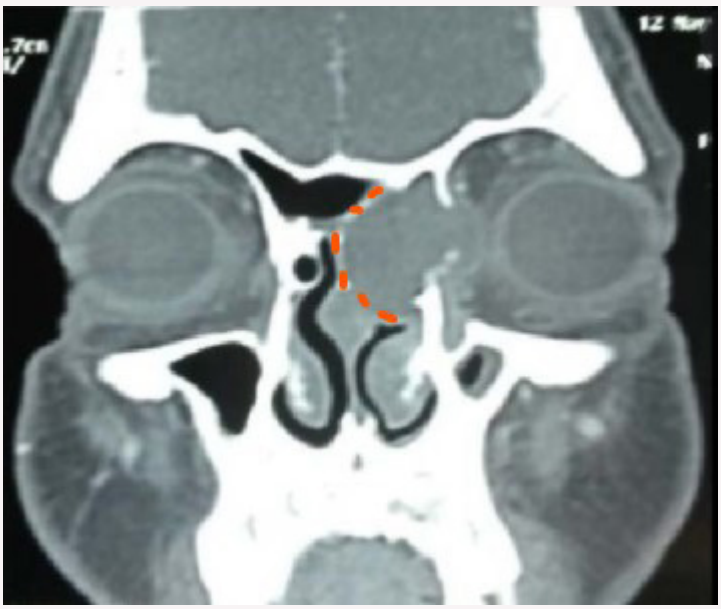
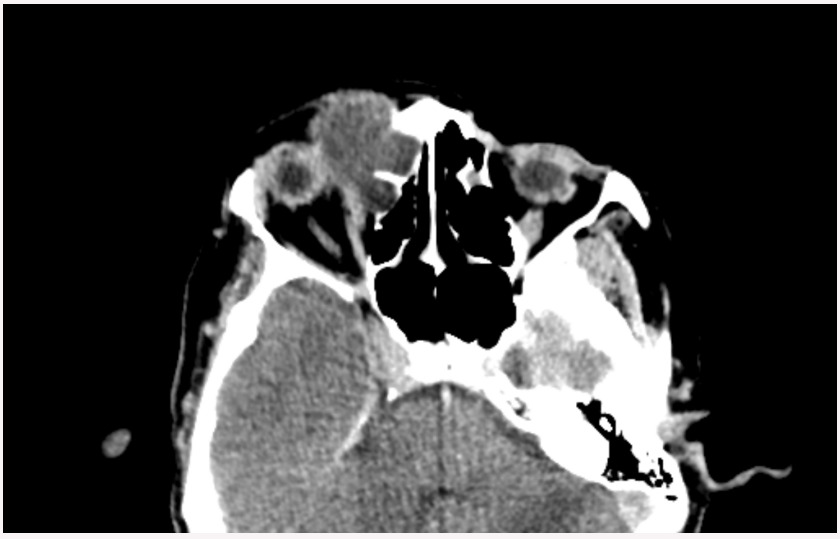
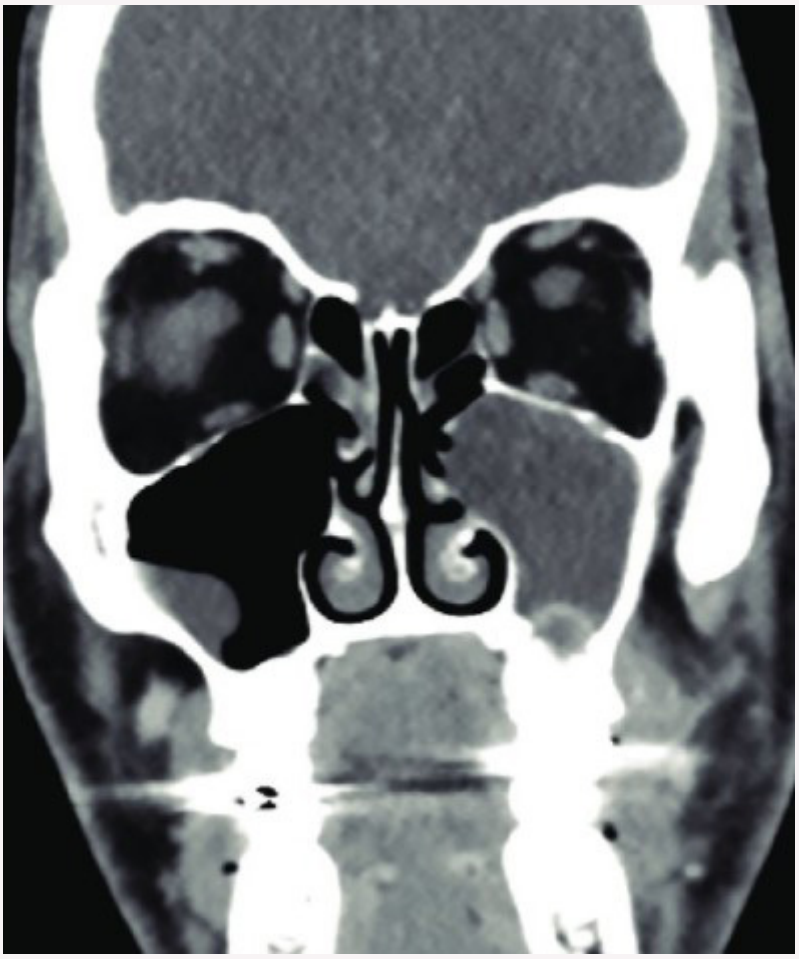


Image showing frontoethmoidal mucocele (Type 2). Here mucoele is found involving both ethmoidal and frontal sinuses

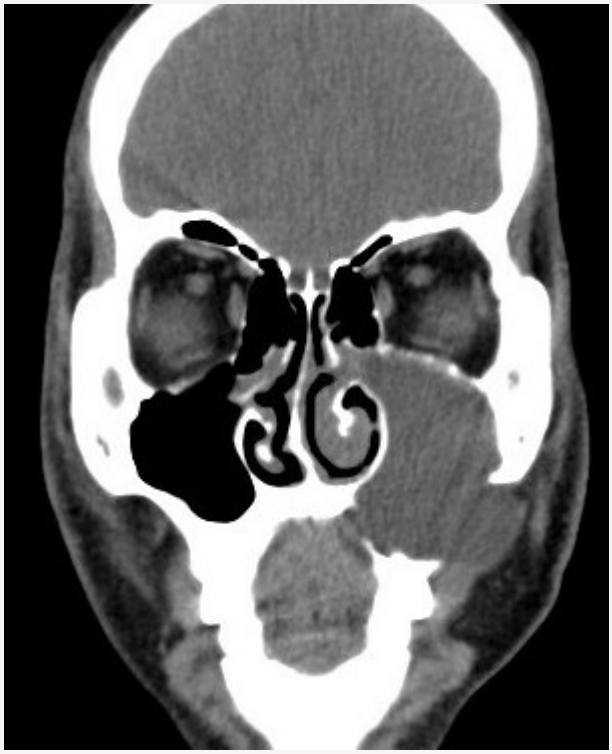
Coronal CT of nose and sinuses showing frontal mucocele left side breaching the floor and entering left orbit pushing the eyeball downwards and laterally (Bone window)



Axial CT nose and sinuses showing frontal mucocele on the right side pushing the left orbit laterally (Bone window)



Coronal CT scan showing periapical lucency extending form tooth #14, resulting in localized left maxillary odontogenic sinusitis.



Coronal CT of nose and sinuses showing a large expansile fluid filled left maxillary sinus cavity (This is a bone window CT) There is obvious thinning of maxillary sinus walls

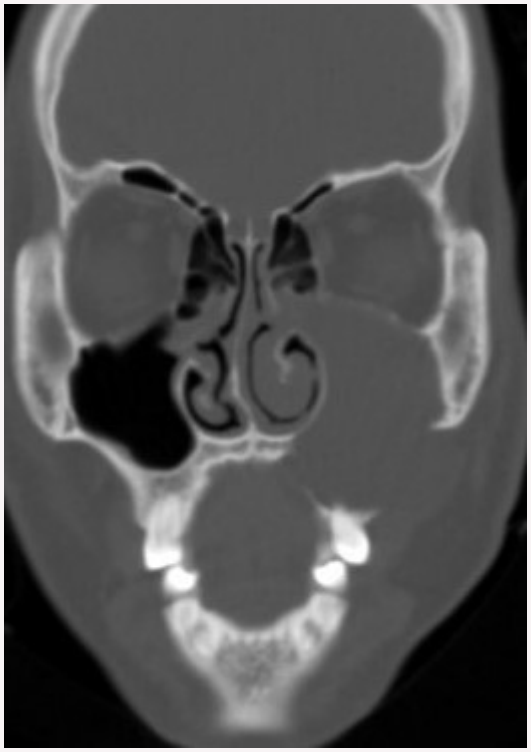
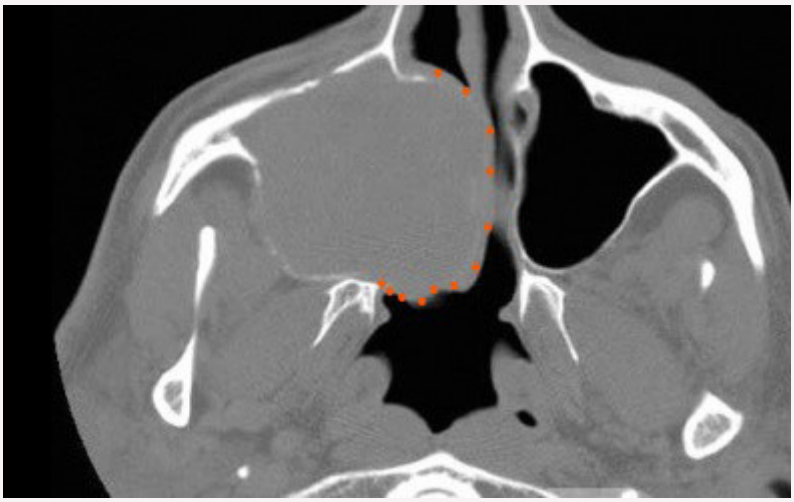


Image showing coronal CT of the same patient (Soft tissue window)

Maxillary sinus mucocele is an unusualy and uncommon lesion which develops inside maxillary sinus due to retained secretions and presents as an expansile cystic lesion. These lesions occur due to obstruction of the sinus ostia and drainage pattern, with accumulation of mucous within the sinus cavity. Continuing accumulation causes it to expand from pressure. Fluid collected within the maxillary sinus is usually sterile and painless. Presence of pain indicates infection.

Obtruction of the sinus ostium has been considered as the primary etiologic factor. Expansion of the sinus cavity occurs due to the direct effect of positive pressure within the mucocele. Local production of bone resorption factors such as prostaglandins, interleukin-1 and tumor necrosis factor have also been identified at the interface betweeen the mucocele and bone.



Axial CT os nose and sinuses showing exapnsile lesion involving right maxillary sinus with erosion of the medial wall of maxillary sinus. Fluid filled sac could be seen pushing the septum to the opposite side.

Fungal Sinusitis

Introduction:

Fungi are eukaryotic organisms comprising of moulds, yeasts, mushrooms and other similar organisms. Among this group of organisms only about 0.1% are human pathogens. The term mycosis is used to define diseases caused by fungi.

Mycosis can be classified under 4 heads based on the portal of entry and site of infection.

Types of Mycosis:

Type	Pathophysiology	Route	Example
Superficial	**Limited to keratinized tissues**	**Topical**	**T Pedis**
Subcutaneous	**Localized to subcutaneous tissues**	**Broken skin**	**Rhinosporidiosis**
Systemic	**Disseminated widely**	**Inhalation**	**Histoplasmosis**
Opportunistic	**Local / disseminated**	**Cell mediated immunity compromise**	**Candida / Mucormycosis**

Fungal infections of nose and sinuses are getting common these days. Withincreasing incidence of HIV and other diseases like diabetes which compromise host immunity it is no wonder that the incidence of fungal infections involving nose and para nasal sinuses is on the rise. In India the incidence of fungal sinusitis in immuno competent patient s is also showing a rise. This particular fact need to be studied further.

Classification of fungal sinusitis: There are 5 different types of fungal sinusitis with differing pathophysiology and clinical presentation. They include:

1. Acute fulminant invasive sinusitis
2. Chronic invasive fungal sinusitis
3. Granulomatous invasive fungal sinusitis
4. Fungal ball
5. Allergic fungal rhino sinusitis

Recently one more group is added i.e. Eosinophilic fungal rhinosinusitis.

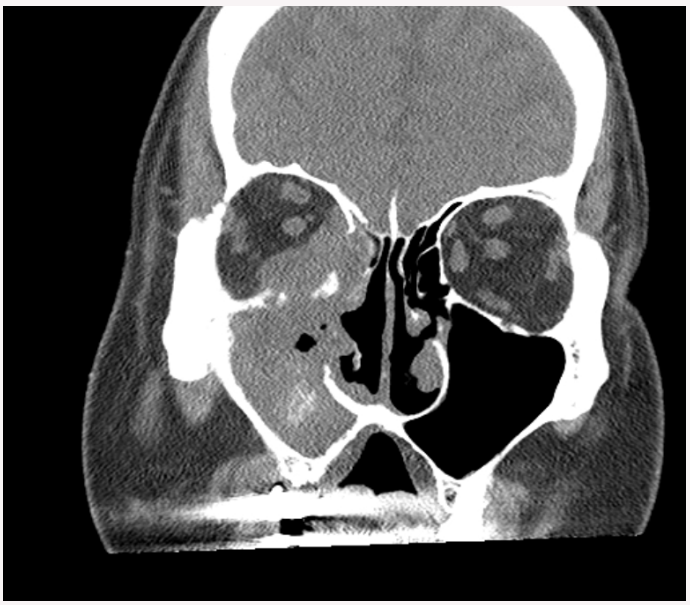
Acute fulminant invasive sinusitis:

The whole duration of illness in these patients is just less than 4 weeks. These patients are mostly immunocompromised individuals. The reduced immunity could very well be a result of
a. Diabetes mellitus
b. AIDS
c. Immunosuppressive medicines
d. Malignancy causing immune suppression

Acute fulminant invasive fungal sinusitis is caused by fungal infections due to:

1. Mucoracea family – seen under microscope as broad hyphae which very rarely septates. Branching out is seen at right angles. This is clearly seen under methanamine / PAS staining of the tissue.
2. Aspergillous family – seen under the microscope as narrow and septate hyphae. Branching could be seen to occur at acute angles.
If mucor is the offending pathogen then it is angioinvasive causing extensive destruction of bone and soft tissue. These patients have a very high mortality rate.

Considering the amount of tissue necrosis involved in these patients, surgical debridement followed by intravenous antifungal medications (amphotericin B) is the treatment of choice. This should also be associated with good euglycaemic control. Since granulocytes are necessary in combating this condition, granulocyte transfusion has been attempted with certain degree of success in these patients following wound debridement.



Coronal CT of nose and sinuses showing features of acute fulminant invasive fungal sinusitis

CT scan features of acute fulminant invasive fungal sinusitis include:

1. Acute infections generally does not demonstrate hyperdense material within the sinus.

2. Mucosal thickening (hypoattenuating)

3. Opacification of the sinus : soft tissue attenuation

4. Bone destruction: may be extensive or subtle or even inapparent (in this case extension through intact bone via vascular invasion)

5. Nasal septal ulceration

6. Fat stranding outside the sinus perimeter

Intraorbital fat
Periantral fat
Nasolacrimal duct
Lacrimal sac
Masticator space
Pterygopalatine fossa

Imaging findings could be mild, particularly in the early phases of the disease. The degreee of sinonasal mucosal thickening could be mild and is not sensitive / specific for the diagnosis of the disease. Presence of any one of the above findings should raise suspicions of invasive fungal sinusitis in high risk patients. Mild periantral fat stranding is often the first sign of vascular invasion and spread beyond the paranasal sinuses.

Chronic invasive fungal sinusitis:

This condition is also known as non granulomatous chronic invasive fungal sinusitis. This condition is commonly seen in patients with diabetes mellitus.

Feature of this infection is low grade inflammation with tissue necrosis. Usually this disease lasts between 4-6 weeks. Vascular invasion is not seen. Granuloma formation is classically seen. Orbital involvement (Orbital apex syndrome)is common in these patients. This condition affects immunocompetent patients. Fronto ethmoidal region is commonly involved. Maxillary sinus and sphenoid sinus are very rarely affected. More than 80% of these patients have fronto ethmoidal sinus involvement. Aspergillosis have been implicated as the commonest pathogen involved.

Orbital apex syndrome is characterized by:

1. Decrease in vision
2. Ocular immobility
3. Proptosis

Axial CT showing acute fulminant invasive fungal sinusitis involving the right ethmoidal sinus with extension into the orbit. Note destruction of medial wall of orbit

Ideally these patients are managed by surgical debridement followed by systemic antifungal drugs like amphotericin B infusion.

Chronic invasive fungal sinusitis is rather rare. According to Ferguson (2005) it constitutes less than 0.003% of all forms of fungal sinusitis operated on.

CT scan coronal cut nose and sinuses of a patient with chronic invasive fungal sinusitis with orbital involvement (Note asymmetrical involvement of the sinuses. This is a clas sic feature of fungal sinusitis)

Coronal Scan of nose and sinuses showing features of chronic invasive fungal sinusitis

CT findings:

CT shows homogeneous opacification of the affected sinuses, iso to hyperattenuating to muscle tissue. Other features include:

1. Relative lack of expansion of sinuses

2. Mottled lucencies or irregular bone destruction may be seen

3. Bone erosion localized to the area of extrasinus extension

4. Extrasinus component of the disease could be more prominent than intrasinus component.

5. There may also be sclerotic changes in the bony walls of the affected sinuses representing chronic disease.

Saggital view of CT PNS showing opacity of maxillary sinus with evidence of mycetoma (arrow)

Granulomatous invasive fungal sinusitis:

This condition is also known as "Indolent fungal sinusitis". Classically thesepatients have intact cell mediated immune response. These lesions are caused by Aspergillus flavous Clinically this condition is indistinguishable from chronic invasive fungal sinusitis. This is actually a histopathological entity. The intact cell mediated immunity limits the lesion to he surface mucosa. Granulomas could be seen surrounding the fungal elements there by effectively preventing their invasion.

Granulomas typically non caseating and demonstrate the presence of multinucleated giant cells and eosinophils. This condition is effectively managed by surgical debridement. After successful wound debridement the intact immune system takes care of the disease. Treatment with itraconazole / variconazole has shown promising results.

Coronal CT scan image showing hetero dense bone destructive lesion involving right maxillary sinus with destruction of its superior and anterolateral walls. (Note small opaque particles within the mass. These are caused by metallic elements within the fungal mass).

Fungal Ball:

These are also known as mycetomas. Mycetomas commonly present as unilateral opacification of maxillary/sphenoid sinuses. This condition is rather rare in ethmoid and frontal sinuses7. Fungal ball is composed of tightlypacked hyphae mostly from (aspergillus, alternaria and P. Boydii). This is actually a sequestration of fungal hyphal elements within the sinus without any invasive / granulomatous changes. Nasal mucosa is absolutely normal in these patients. This disease is classically caused due to inhalation of spores, which eventually gets sequestered either into maxillary or sphenoid sinuses.

Coronal CT image showing opacifiation of left maxillary sinus extening into the orbital floor and pterygoplatine fossa.

Fungal growth occurs within the confines of the affectedsinus cavity. Fungal growth occurs because of the ability of the infecting pathogen to avoid host immune response. Signs and symptoms may mimic chronic rhinosinusitis in advanced cases.
Clinical examination reveals very little. CT imaging reveals opacity of the involved sin us cavity.

This condition is managed by surgical removal of the fungal ball and creating good ventilation to the involved sinuses by widening the sinus ostium. Systemic antifungal agents are not indicated in these patients. Topical antifugal agents have been administered with varying degrees of success. In majority of these patients this condition was diagnosed as an incidental finding when routine imaging of nose and sinuses were performed.

Allergic Fungal sinusitis:

This rather poorly understood entity was first reported in 19768. In 1983 Katzenstein et al described a condition and coined the terminology allergic aspergillus sinusitis. They made the diagnosis based on the presence of histological triad of "clumps / sheets of necrotic eosinophils, Charcot – Leyden crystals probably from degenerating eosinophils and noninvasive fungal hyphae resembling aspergillus species. These patients have a
combination of nasal polyposis, crust formation and positive culture for aspergillus. It was Robson in 19899 who introduced the term allergic fungal sinusitis to describe the findings associated with this disease. According to Cody aspergillus species was responsible for only 15% of allergic fungal sinusitis. This was evident from the retrospective study conducted by him covering alarge sample size.

Incidence of allergic fungal sinusitis among chronic sinusitis is placed around 6-7%. Based on clinical findings Bent and Kuhn proposed certain criteria for diagnosis of allergic fungal sinusitis.

Bent's criteria for the diagnosis of allergic fungal sinusitis:

1. Demonstrable type I hypersensitivity to fungi
2. Nasal polyposis
3. Radiological findings (Heterodense mass lesion)
4. Presence of eosinophilic mucin mixed with non invasive fungus
5. Positive fungal stain / fungal culture

Swain's modification of Bent's criteria:

deShazo and Swain slightly modified the diagnostic criteria laid out by Bent. They left out the type I hypersenitivity criteria alone since only 2/3 of patients with allergic fungal sinusitis manifested with hypersensitivity to fungal protein in various studies.

Bent and Khun modified their diagnostic criteria for diagnosis of allergic fungal sinusitis by adding major and minor diagnostic criteria.

Diagnostic criteria of AFRS

Major criteria	Minor criteria
Type I Hypersensitivity	**Asthma**
Nasal polyposis	**Unilateral disease**
Characteristic CT findings	**Bone erosion**
Eosinophilic mucin	**Fungal cultures**
Positive fungal stain	**Charcot Leyden crystals & eosinophilia**

Undisputed diagnostic criteria for the diagnosis of allergic fungal sinusitis include:

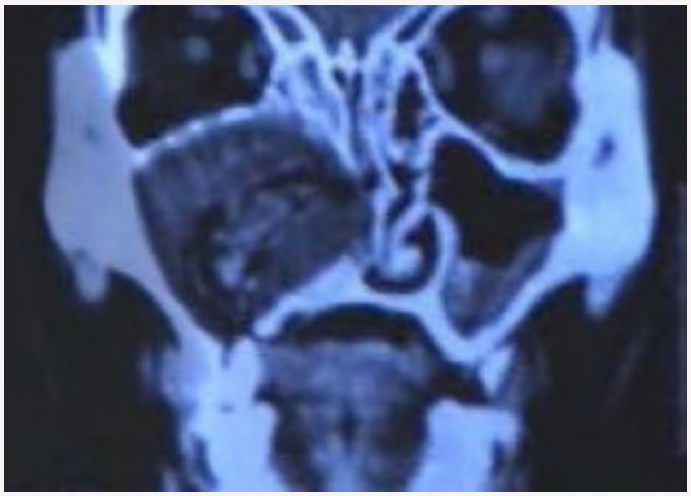
1. Chronic rhinosinusitis
2. Presence of allergic mucin
3. Presence of fungal organism within the mucin

Allergic fungal sinusitis like condition:

In this category those patients who do not demonstrate positive fungal presence in the mucin or in cultures of mucin are included. The paucity/absence of fungal elements in these patients could be accounted for by the presence of increased amounts of major
basic protein released by eosinophils. Major basic protein has been found to be toxic to fungi.

Clinical features of allergic fungal sinusitis:

These patients present with progressive nasal obstruction, crusting, rhinorrhoea, and chronic rhinosinusitis. These patients can also come with dramatic symptoms like visual loss and total nasal obstruction. Classically radiology shows unilaterally expansile lesion of the sinuses associated with bony erosion. The mass appears as heterodense due to the presence of metallic elements in the fungal hyphae. Unilateral asymmetric involvement of sinuses is the classic feature of this condition. The mechanism of causation of allergic fungal sinusitis is IgE mediated hypersensitivity to fungal proteins especially to
aspergillus. Both type I and type III hypersensitivity reactions to fungal proteins have been implicated. Allergic fungal sinusitis still remains an under reported condition due to lack of awareness amongst treating physicians.



Coronal CT nose and sinuses showing Expansile lesion involving the right maxillary si nus. Erosion of medial wall of maxilla, the nasal cavity is filled with heterodense mass. The septum is seen being pushed to the opposite side.

CT scan features of AFRS:

CT scan paranasal sinuses reveal multiple opacified sinuses with central hyper attenuation, mucocele formation, erosion of lamina papyracea / skull base, pushing borders. Bone erosion in patients with nasal polyposis should raise suspicion of allergic fungal sinusitis.

Eosinophilic fungal sinusitis:

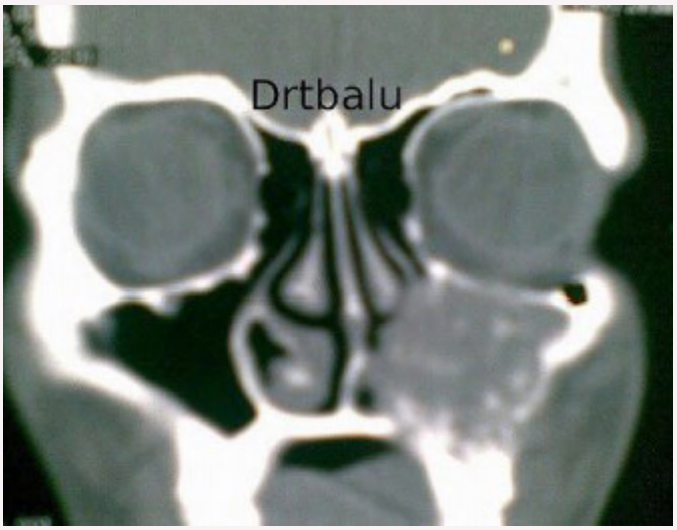
This terminology was introduced by Ponikau etal to explain pathophysiology of chronic sinusitis. This disorder is usually bilateral. Fungal hyphae has been demonstrated in almost all these patients. Studies have not managed to demonstrate increased
levels of IgE in these patients. Hypersensitivity reaction has been ruled out asa cause for this type of fungal sinusitis. It has been postulated that this condition could be caused by abnormal cell mediated immunity to fungal proteins.

These patients respond well to surgical removal of polypoidal mucosa, and creation of wide antrostomy which improves ventilation to the sinus mucosa.

Coronal CT scan of nose and sinuses showing evidence of fungal polyposis inside both nasal cavities with erosion of skull base on the right side. Both maxillary sinuses are ob structed with pent up secretions.

Coronal CT scan of paranasal sinuses (posterior cut) showing opacity of sphenoid sinus with erosion of sphenoid sinus roof. Fungal Sphenoidal sinusitis

Coronal CT scan of paranasal sinuses (posterior cut) showing opacity of sphenoid sinus with erosion of sphenoid sinus roof. Fungal Sphenoidal sinusitis



Coronal CT scan nose and sinuses showing fungal sinusitis of maxillary sinus

Coronal CT showing heterodense mass lesion occupying the left nasal cavity and extending up to left frontal sinus. Note: Medial orbital wall is thin and slows evidence of remodelling. Unilateral heterodense lesion is considered to be a feature of AFRS. Nasal septum appears to be pushed to the right side

Coronal CT of nose and sinuses showing heterodense lesion occupying left maxillary sinus with destruction of the medial wall of maxilla. The same lesion can be seen extending into the nasal cavity. Medial wall of the orbit shows thickening and evidence of remodelling when compared to that of opposite side. This feature is suggestive of AFRS.

Nasal Polypi

Definition:

Polyp is defined as simple oedematous hypertrophied mucosa of the nasal cavity. It can be unilateral/bilateral1. Prevalence of nasal polyp in general population has been estimated to be around 4%.

Causes of nasal polyp:

1. Infections
2. Allergy
3. Polyp due to mucovisidosis

Classification:

Nasal polyp can be classified as:

1. Simple polyp
2. Ethmoidal polypi
3. Antrochoanal polyp
4. Fungal polyp
5. Malignant polyp

Imaging plays a crucial role in the diagnosis and management of nasal polypi.

The following are some of the important contributions imaging is supposed to make:
It clinches the diagnosis
It helps in evaluation of progression of disease
Helps in surgical planning
Helps in monitoring for recurrence

CT appearance of nasal polypi:

They appear as rounded bodies of soft tissue arising from the mucosal surfaces of nose and para-nasal sinuses. They can be clearly differentiated from the surrounding inflammed mucosal lining and nasal secretion as they are more radio dense and hence appear brighter. Rarely a pedicle attaching the polypoidal mass to the nasal mucosal lining can be seen clearly in the CT scan (pedicle sign). If present it is virtually diagnostic of nasal polypi.

One important point that should be borne in mind while evaluating CT images from a patient with nasal polypi is that they never cause bone erosion. If soft tissue mass arising from the nasal mucosa is associated with bone erosion then it is a definite pointer towards the diagnosis of malignancy. Pressure effects of nasal polyp can be evidently seen in imaging. These effects include local bone remodelling causing a scalloping effect. This scalloping effectshould not be confused with that of the scalloping of margins produced bythe mucocele since it is always associated with enlargement of the sinus cavity. Rarely this bone remodelling may occasionally cause thinning of the bony septa of the ethmoidal sinus. This thinning could be so extreme that it could go even below that of the resolution of the CT scan. This creates a picture of bone erosion which is not a true one.

Appearance of nasal polyp when contrast CT is taken:

Nasal polypido not show enhancement on injection of contrast media. The mucosa surrounding the nasal polyi may show enhancement causing an impression of rim enhancement around the nasal polypi.

Types of nasal polyp:

Ethmoidal polypi– arising from ethmoidal sinus and are multiple. They can be visualized in the CT scan of paranasal sinuses as multiple polypoid lesions. Polypi arising close to the cribriform plate area can cause olfactory disturbances.

Polyp arising from the maxillary sinus – is usually solitary.

It exits the antrum via the natural / accessory ostium. This causes an enlargement of ostia. Radiologically it appears like a dumbbell because of the constriction present in the midline (ostial exit point). In these patients the medial wall of the maxillary sinus bows into the nasal cavity. This can be clearly visualized in the CT scan images. Obstruction caused by this polyp to the drainage channels of ethmoidal and frontal sinuses (middle meatus) can causeopacification of those sinuses also there by making it difficult to identify theexact origin of the nasal polyp. In this scenario the bone remodelling that takes place in the medial wall of maxillary sinus could be the clincher. If these polyp passes posteriorly to exit via the choana it could be clearly visualized in the axial cuts taken at the choanal level.Fungal disease may coexist with nasal polypi. If present they could be visualized as hyper dense areas between the nasal polypishadows.

CT differences between acute sinusitis & nasal polypi:

Acute sinusitis causes a near uniform Opacification of the paranasal sinuses whereas nasal polypi in addition to the Opacification show multiple convexities.

Mucous retention cyst can be safely eliminated if the polyp shows a pedicle radiologically. If there is associated bone remodelling then in all probability it could be nasal polyp rather than mucous retention cyst. In case of diagnostic dilemma MRI will clinch the diagnosis.

In cystic fibrosis in addition to the radio densities seen in the CT scan images there is also associated thickening of the maxillary sinus walls due to osteoneogenesis.

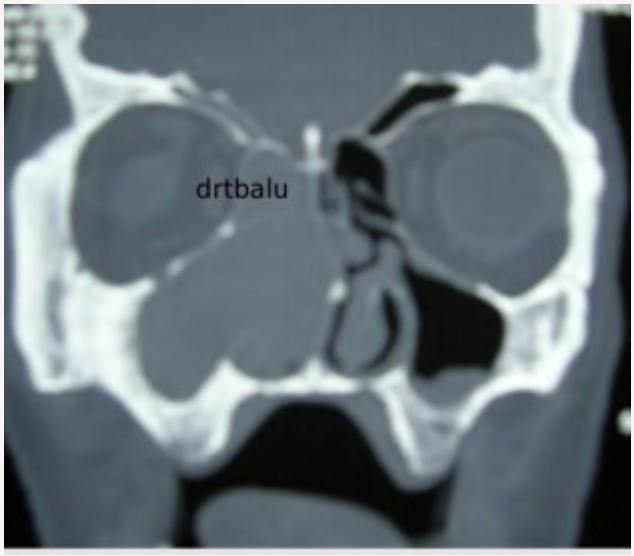


Image showing coronal CT of Nose and sinuses showing unilateral nasal polyposis with evidence of bone remodelling.

Differences between Ethmoidal polypi and Antrochonal polyp

Ethmoidal Polypi	*Antrochoanal polyp*
Seen in adults	*Seen in children and adolescents*
Allergy is the common cause	*Infection*
Multiple & bilateral appearing like a bunch of grapes	*Unilateral & Single*
Arises from ethmoidal labyrinth	*Arises from maxillary antrum*
Seen in anterior rhinoscope	*Seen in posterior rhinoscopy*
X-ray shows normal antrum with hazy ethmoidal labyrinth	*X-ray shows hazy antrum*
Recurrence - common	*Recurrence Uncommon*

1

Antrochoanal polyp:

Synonyms:

Antrochoanal polyp, Killian's polyp, Nasal polyp.

History:

In 1753 Palfyn first described an antrochoanal polyp in a female patient. The polyp was found filling the nasopharynx extending up to the uvula of the patient. Palfyn believed that this polyp arose from the choana. It was Killian in 1906 who demonstrated that this polyp arose from the maxillary sinus antrum.

Definition:

Antrochoanal polyp is a benign solitary polypoidal lesion arising
from the maxillary sinus antrum causing opacification and enlargement of antrum radiologically without any evidence of bone destruction. It exits the antrum through the accessory ostium reaches the nasal cavity, expands posteriorly to exit through the choana into the post nasal space.

Incidence:

It commonly affects children and young adults.
Etiopathogenesis: This disease is commonly seen only in non atopic persons.

Its etiology is still unknown. In fact this disorder is not associated with nasal allergy.

Etiopathogenesis:

This disease is commonly seen only in non atopic persons.
Its etiology is still unknown. In fact this disorder is not associated with nasal allergy.

Proetz theory: Proetz suggested that this disease could be due to faulty development of the maxillary sinus ostium, since it was always been found to be large in these patients. Hypertrophic mucosa of maxillary antrum sprouts out through this enlarged maxillary sinus ostium to get into the nasal cavity.

The growth of the polyp is due to impediment to the venous return from the polyp. This impediment occur at the level of the maxillary sinus ostium. This venous stasis increases the oedema of the polypoid mucosa thereby increasing its size.

Bernoulli's phenomenon: Pressure drop next to a constriction causes a suction effect pulling the sinus mucosa into the nose.
Mucopolysaccharide changes: Jakson postulated that changes in mucopoly saccharides of the ground substance could cause nasal polyp.

Infections: Recurrent nasal infections have also been postulated as the cause for nasal polyp.

Mill's theory:

Mills postulated that Antrochoanal polyp could be maxillary mucoceles which could be caused due to obstruction of mucinous glands.

Ewing's theory:

Ewings suggested that an anomaly which could occur during maxillary sinus development could leave a mucosal fold close to the ostium. This fold could later be aspirated into the sinus cavity due to the effects of inspired air causing the development of antrochonal polyp.

Vasomotor imbalance theory: This theory attributes polyp formation due to autonomic imbalance Polypoidal tissue from the maxillary antrum exits out through the accessory maxillary sinus ostium according to some workers.

This accessory sinus ostium is placed posteriorly, which could be the reason for the polyp to present posteriorly. The accessory sinus ostium widens progressively, ultimately at one stage merging with the natural ostium of the maxillary sinus forming one huge opening into the maxillary antrum.

Infection / Inflammation:

This theory suggests that acinous mucous glands within the maxillary sinus cavity gets blocked due to infection / inflammation involving the mucous lining of the sinus cavity. This leads to the formation of a cystic lesion within the
maxillary sinus cavity. This cyst gradually enlarges to occupy the whole of the maxillary sinus cavity. It exits the sinus cavity by enlarging the accessory ostium and enters the nasal cavity. Usually these cysts arise from the antero inferior / medial wall of maxillary antrum.

Possible reasons for migration of Antrochoanal polyp in to the post nasal space:

1. The accessory ostium through which the polyp gets out of the maxillary antrum is present posteriorly.
2. The inspiratory air current is more powerful than the expiratory air current thereby pushes the polyp posteriorly.
3. The natural slope of the nasal cavity is directed posteriorly, hence the polyp always slips posteriorly.
4. The cilia of the ciliated columnar epithelial cells lining the nasal cavity always beats antero posteriorly pushing the polyp behind.

Histology: Shows respiratory epithelium over normal basement membrane.
The interstitial layer is grossly oedematous, with no eosinophils. The interstial layer contains other inflammatory cells.

Clinical features:

Since the disorder is unilateral (commonly) the patient always present with:
1. Unilateral nasal obstruction

2. Unilateral nasal discharge
3. Headache (mostly unilateral)
4. Epistaxis
5. Sleep apnoea
6. Rhinolalia clausa due to presence of polyp in the post nasal space
7. Difficulty in swallowing if the polyp extends into the oropharynx

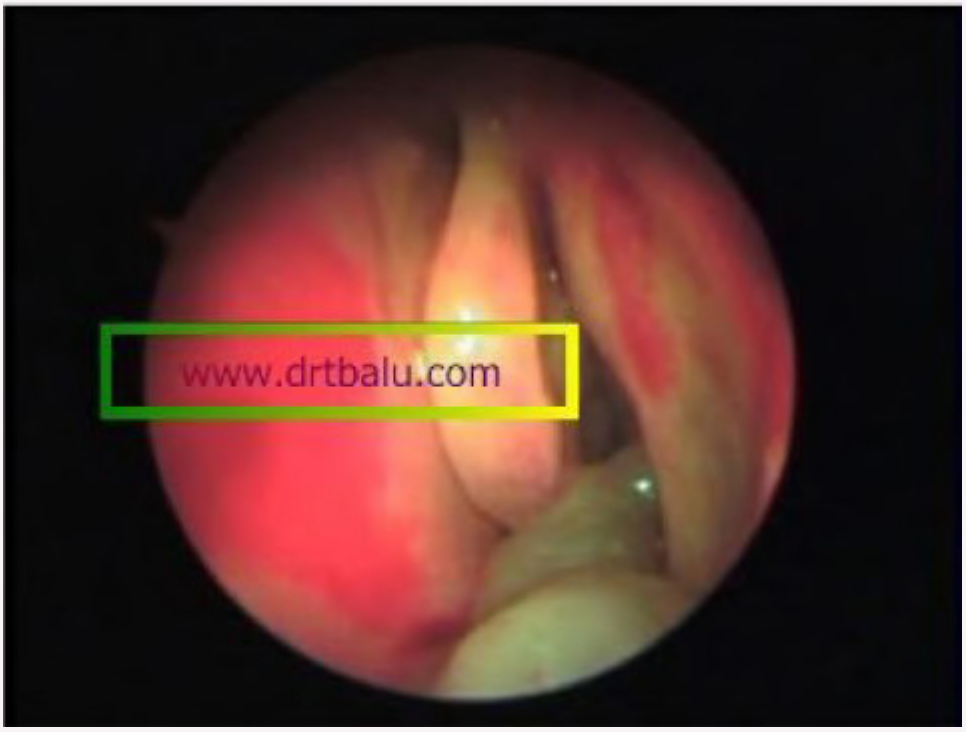
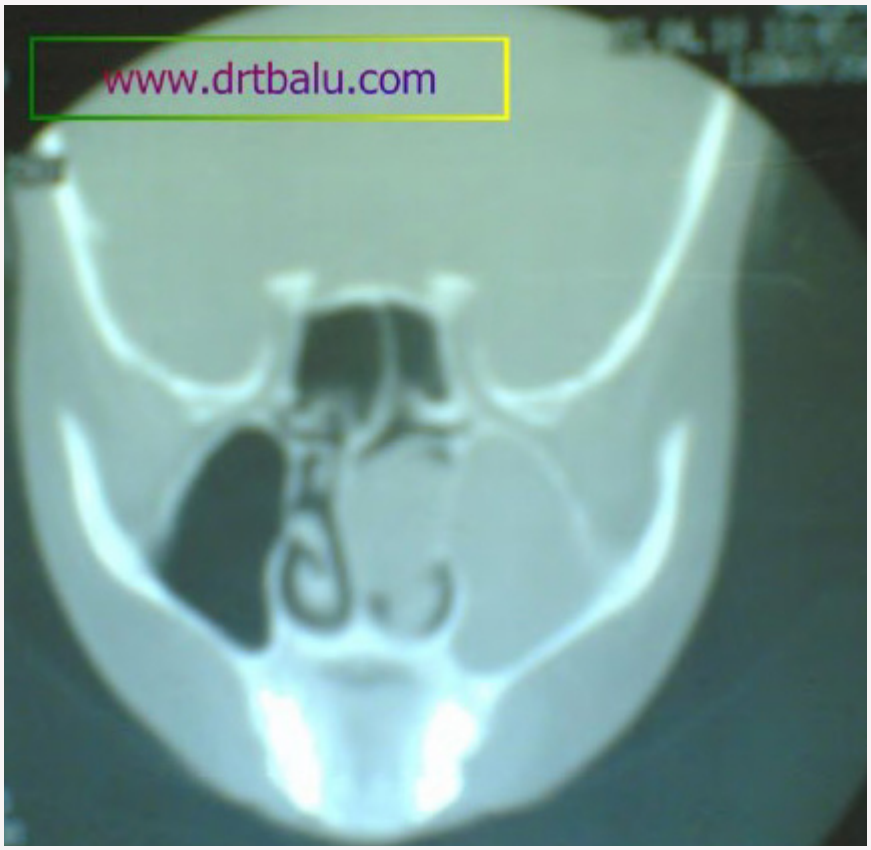
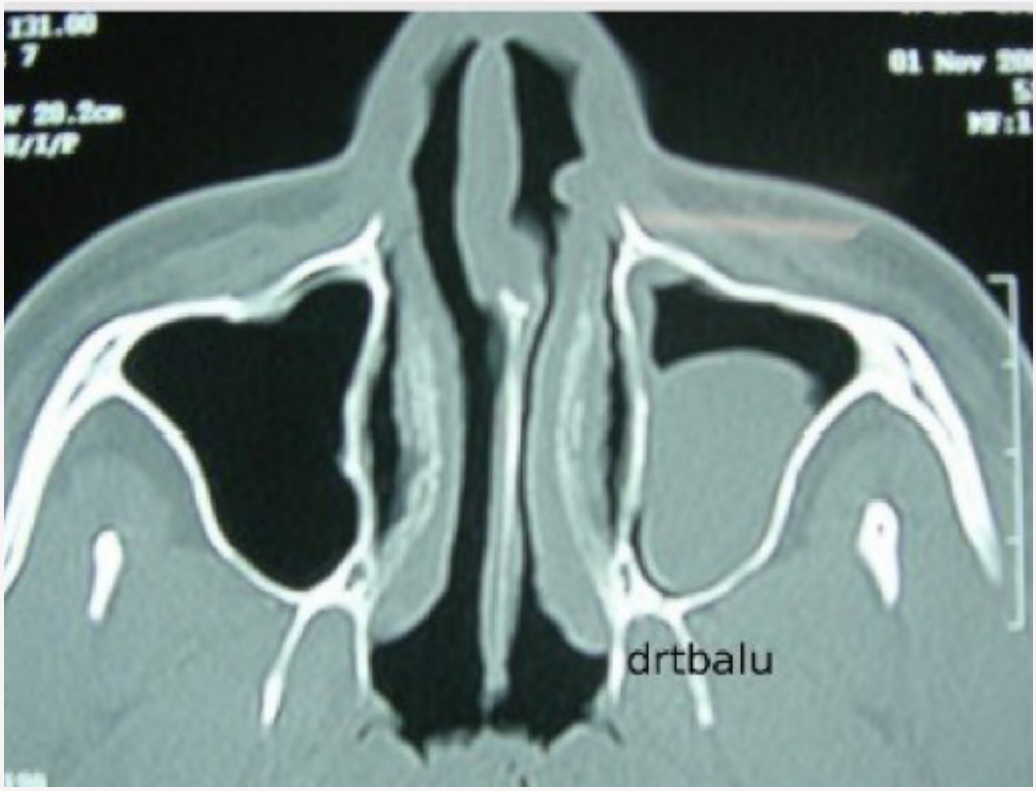


Image showing endoscopic view of antrochoanal polyp

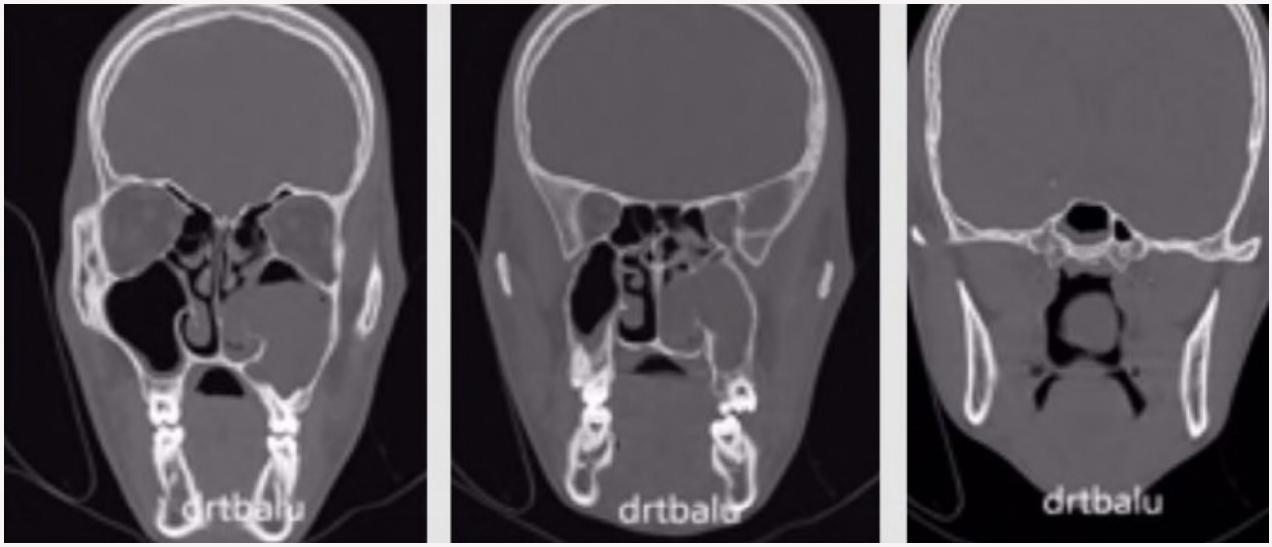
CT scan of paranasal sinuses is diagnostic. It will show the polyp filling the maxillary antrum and exiting out through the accessory ostium into the nasal cavity.



Coronal CT of nose and sinuses showing Antrochoanal polyp. (Note the antral compo nent and the nasal component)



Axial CT nose and sinuses showing cyst within left maxillary sinus cavity. (Radio opacity iis similar to that of soft tissue). This is suggestive of mucous retention cyst which is a precursor of Antrochoanal polyp.



Serial Coronal CT images showing Antrochoanal polyp

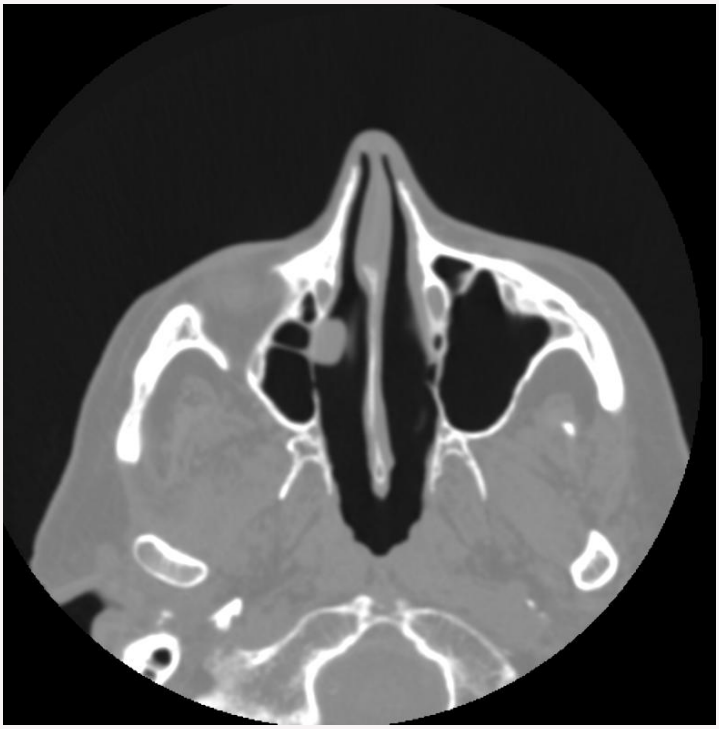
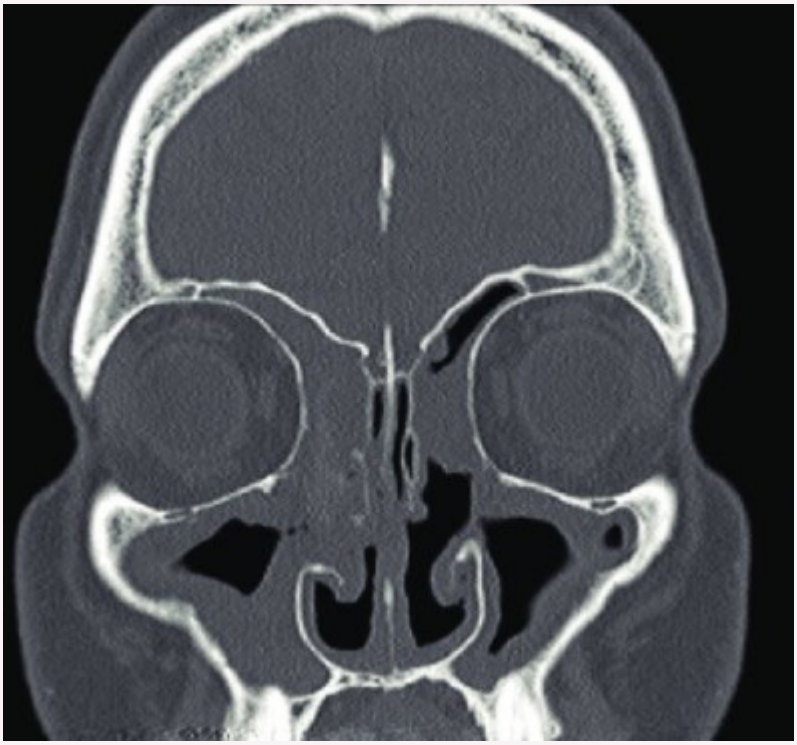


Image showing axial CT of nose and sinuses with radio opaque mass inside the right nasal cavity in the ethmoidal area. Probably a nasal polyp.



Coronal CT of nose and sinuses showing eivdence of chronic rhinosinusitis with nasal polypi. There is extensive polyposis lining both maxillary, ethmoid and frontal sinuses.

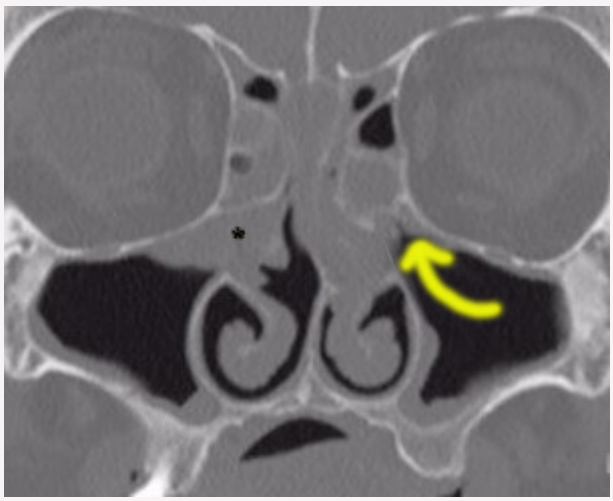
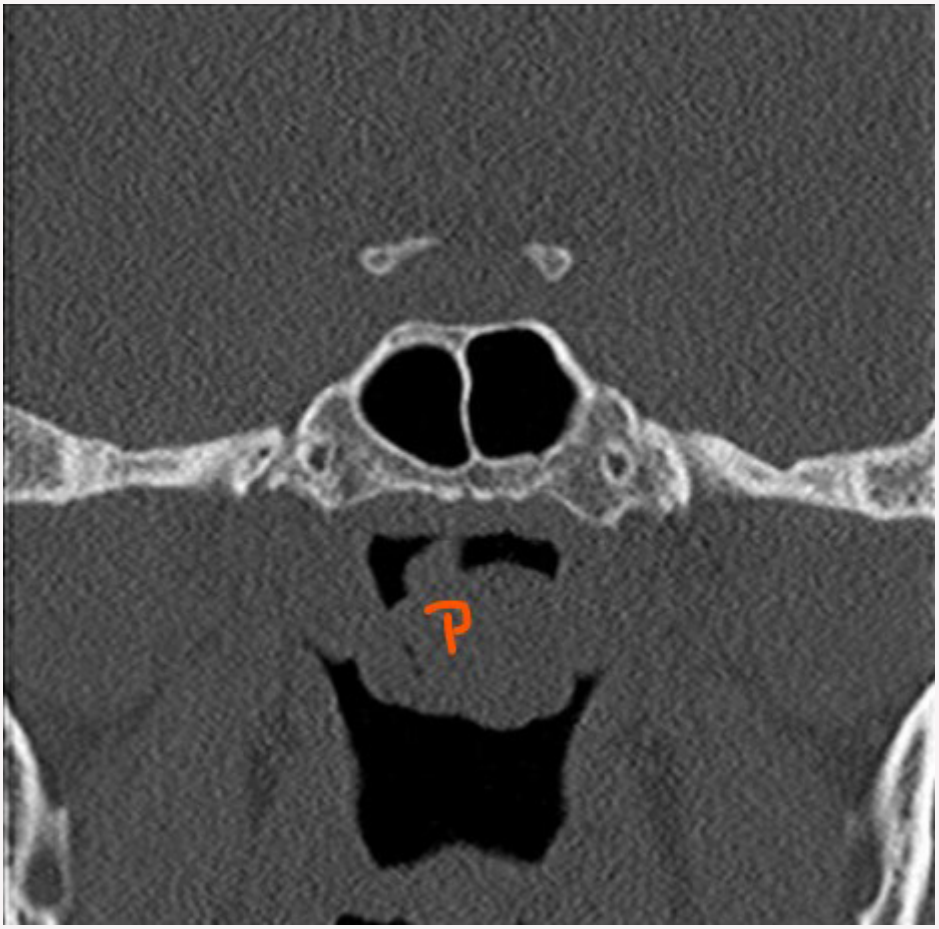


Image showing coronal section through maxillary sinus ostia. Curved yellow arrow indicates left maxillonasal canal; asterix indicates suspected prolapse of ethmoidal polyp in to right maxillary sinus.

Image showing cornal CT of nose and sinuses demonstrating antro chonal polyp on the left side. It exhibits three portions. Portion 1 - antral component, Portion 2 - Nasal component and Portion 3 - Choanal component

Image showing coronal section taken at the level of choana with polyp occluding left choana. This is the third component of antrochoanal polyp



Coronal CT at the level of Nasopharynx showing polyp partially filling the cavity

CT features of antrochoanal polyp:

1. Well defined mass with mucin density is seen arising from maxillary sinus.

2. Accessory ostium of maxillary sinus is widened and the mass extrudes via it.

3. There is no evidence of associated bony destruction and there is only a smooth enlargement of the sinus.

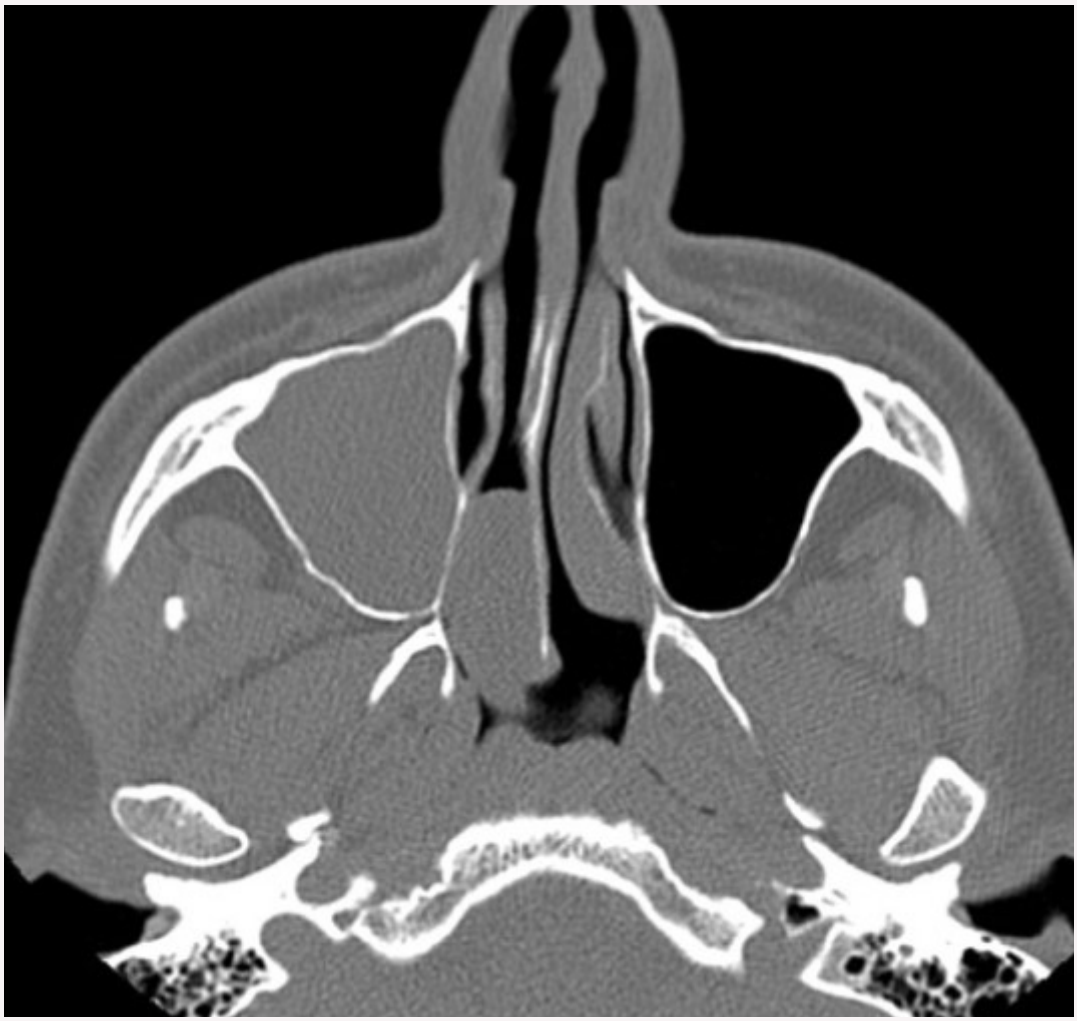
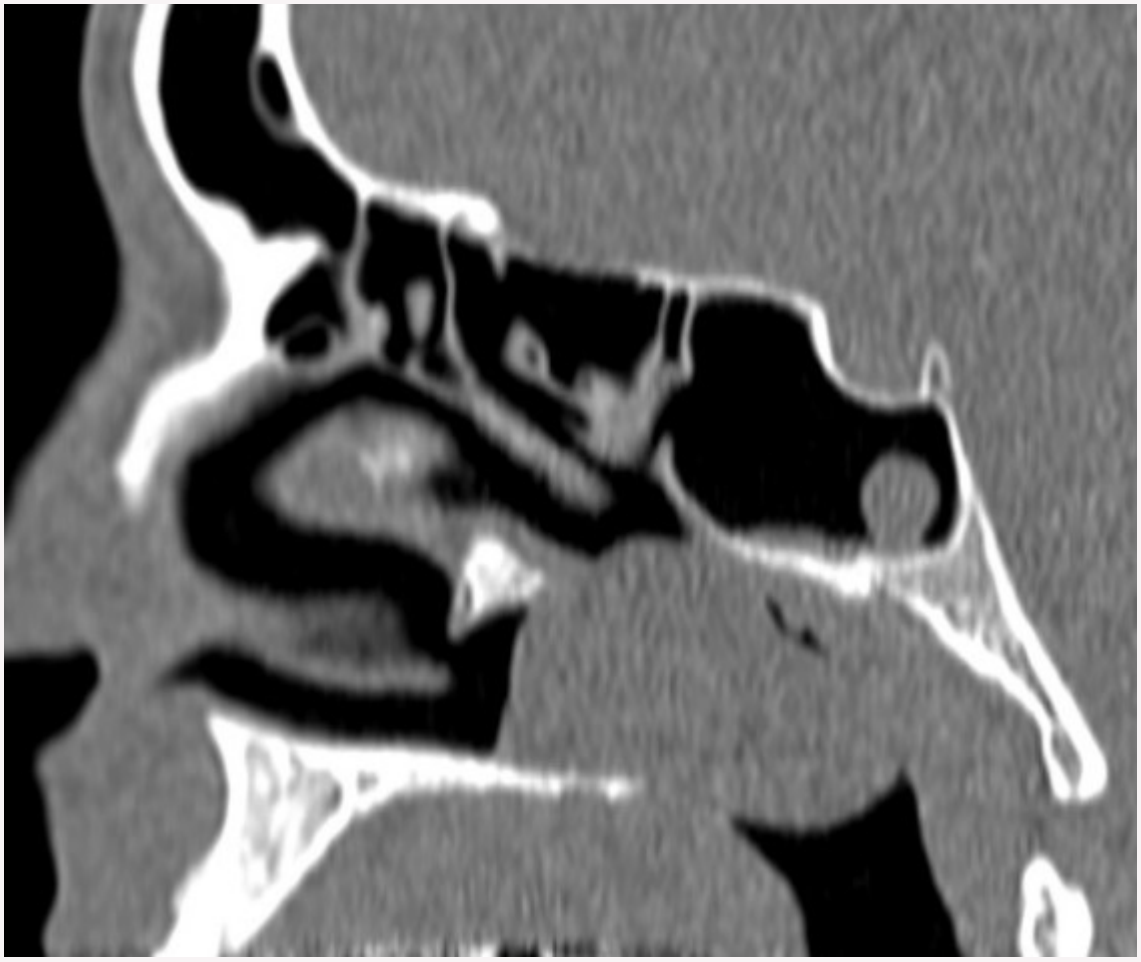
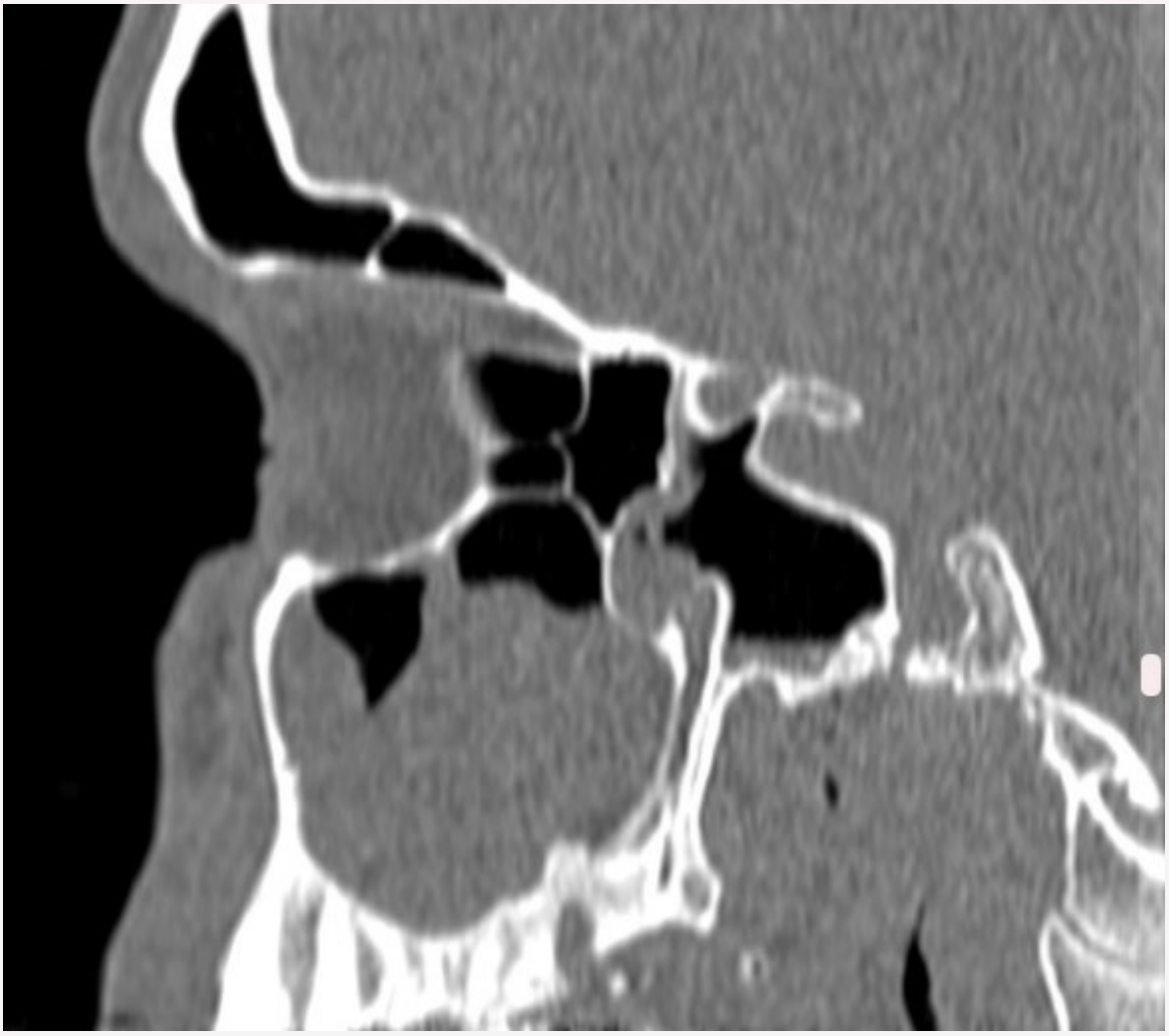


Image showing axial CT of nose and sinuses (Bone window). Soft tissue shadow seen filling maxillary sinus and another soft tissue shadow is seen filling the posterior portion of nasal cavity. There is no evidence of bone erosion. Probable diagnosis is nasal polposis.

Axial CT showing antrochoal polyp arising from right maxillary sinus extruding out of accessory ostium and entering into the nasal cavity. Note the dumb bell shape of the lesion and the air shadow posterior to the mass in the nasopharynx. There is also no evidence of bone erosion which rules out malignant lesions.



CT sagittal section of nose and sinuses showing a solitary polyp filling the posterior portion of the nasal cavity and extending up to the nasopharynx. Note side cannot be commented in this view.



CT saggital section showing soft tissue shadow filling majority of the maxillary sinus cavity. There is no evidence of destruction of bony wall. Probable diagnosis is polyp filling the maxillary antrum. Side cannot be commented on. One small tip is if this cut is found at the begining of the CT screening it should be left maxillary sinus since sanning process always commences on the left side and progresses to the right side.

Radiologic features of Benign sinonasal neoplasms

Sinonasal neoplasms are rare accounting for about 3% of head and neck tumors. CT scan is often the first imaging modality that is performed in these patients. These images help in the assessment of following features of the tumor:

1. Size of the lesion

2. Extent of the lesion

3. Presence of tumoral calcification

Most tumors involving the sinonasal area show nonspecific imaging features hence histopathologic diagnosis should be relied upon. Findings classically seen in benign tumors of nose and sinuses include bone remodeling / thickening of adjacent bone.

Bening neoplasms can also present with nonspecific signs and symptoms that could mimic rhinosinusitis. These include:

Unilateral nasal obstruction

Nasal discharge

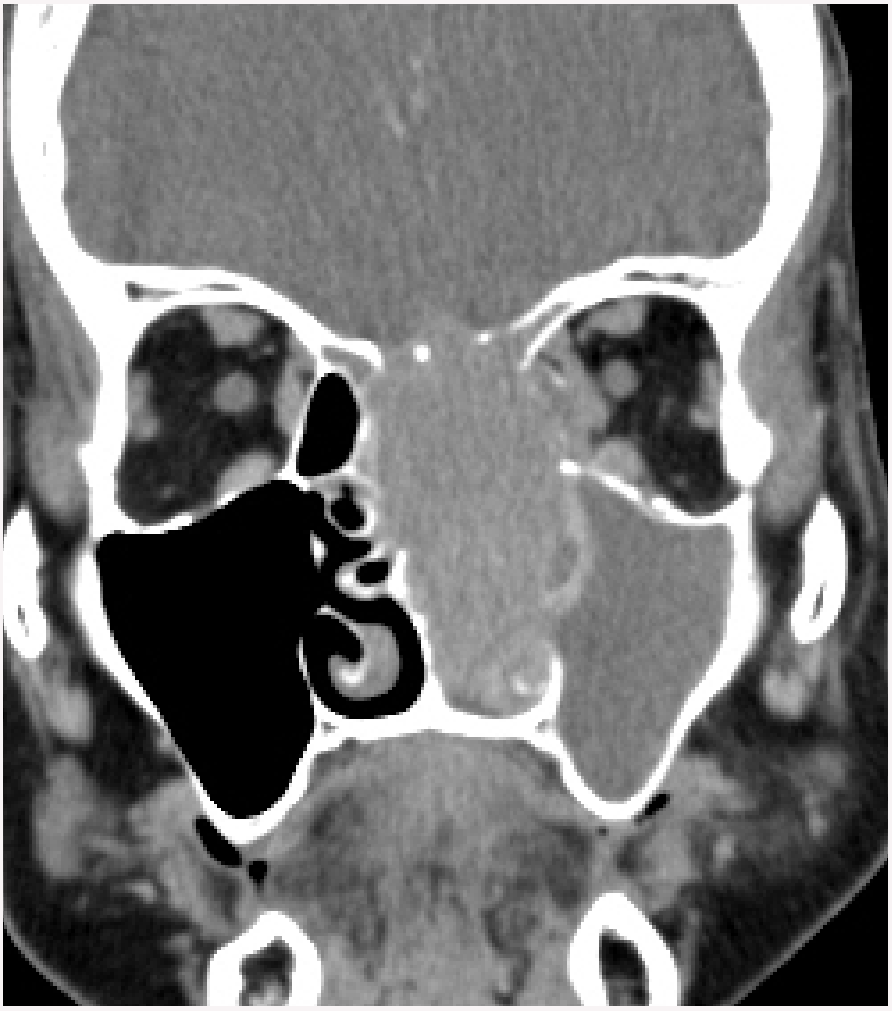
Headache

Epistaxis - Common in vascular tumors

Benign epithelial tumors include papillomas and salivary gland type adenomas, the most common of which is the pleomorpic adenoma.

Epithelial tumors:

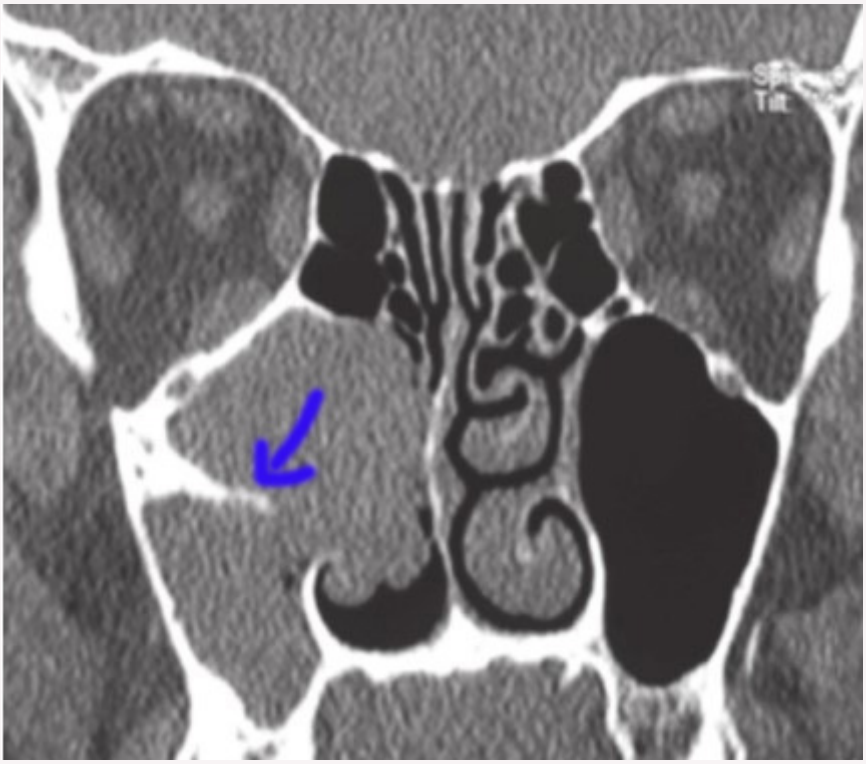
Papillomas are the most frequently encountered benign epithelial neoplasms and inverted papilloma is the most common subtype. Inverted papilloma is a benign but locally aggressive tumor. The term inverted refers to the histology of the lesion as it demonstrates an endophytic growth pattern. This condition is seen in patients during the 5th-7th decades.



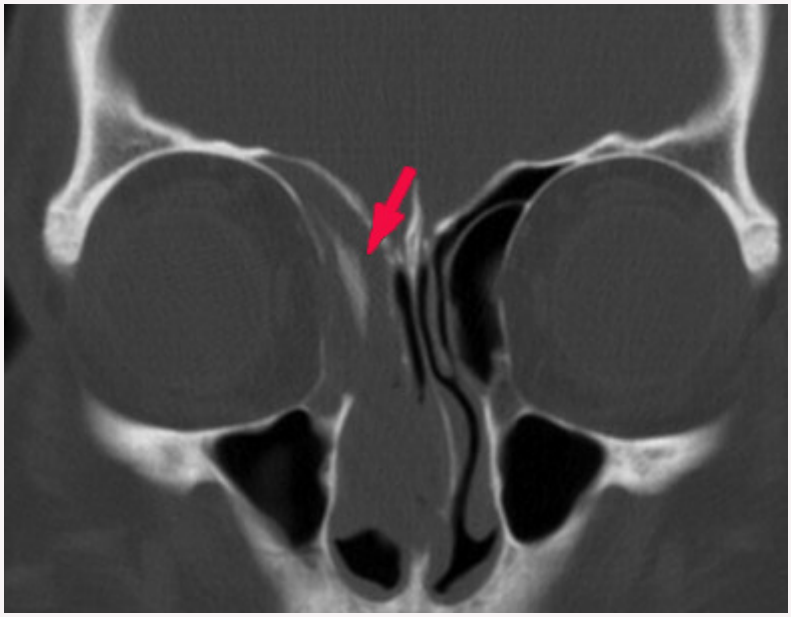
Coronal CT of nose and sinuses showing soft tissue shadow in the left nasal cavity with opacity (uniform) of left maxillary sinus. Contrast enhancement (moderate) seen in the nasal mass. Note erosion of skull base. Opacity of left maxillary sinus could probably be due to pent up secretions due to obsruction

CT scan of nose and sinuses in these patients demonstrate soft tissue density mass with some enhancement. As the mass enlarges, bony resorption and destruction may be present. Intralesional calcifications representing residual bone fragments are observed in 40% of patients. Presence of a focal, often cone shaped hyperostosis has been reported to correlate with the point of origin of the lesions.

Axial CT showing soft tissue lesion involving nasal cavity with destruction of medial wall of maxilla. Left maxillary antrum could be seen to be filled by the same mass. This finding is suggestive of inverted papilloma of nose.

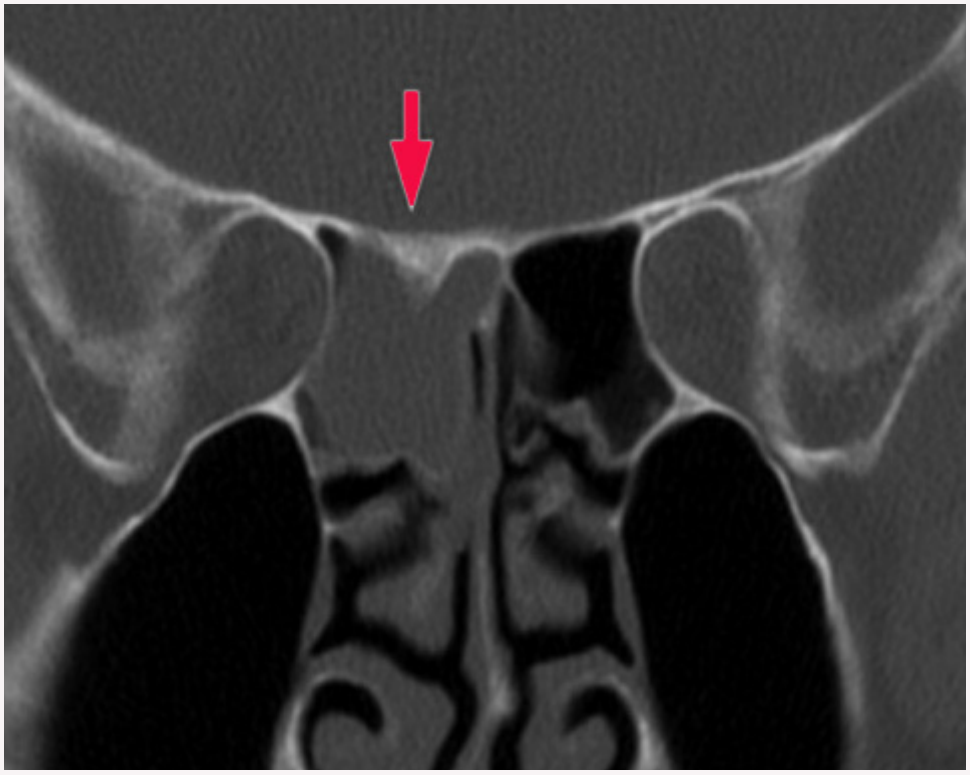


Coronal CT scan of an inverted papilloma of the right maxillary sinus. Note new bone formation (Blue arrow).

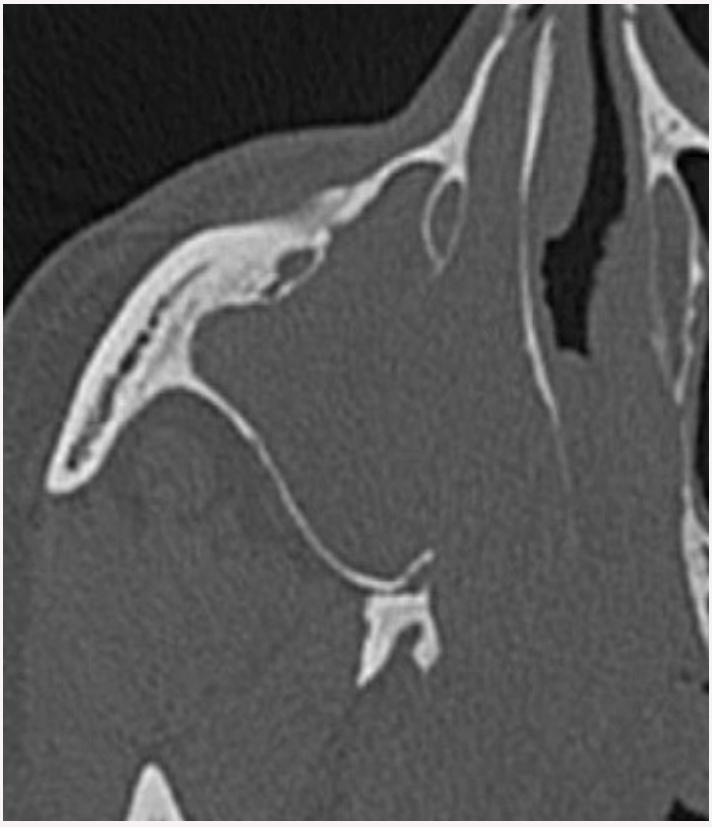


Coronal CT image showing areas of hyperostosis within the tumor mass (inverted papilloma) Red arrow

Areas of focal hyperostosis commonly correspond to the actual tumor origin in nearly 90% of these cases. In these patients, although tumor masses extend to adjacent sinuses / nasal cavity, focal bone thickening was limited to the tumor origin as long as the origin did not extend to adjacent sinuses or the nasal cavity. The difference in thickness between the hyperostotic area and adjacent unaffected bony wall was highy prominent and could result in a cone shaped thickening of the bone.



Coronal CT of a patient with inverted papilloma shows localized cone shaped hyperostosis of the superior wall of posterior ethmoid sinuse (red arrow). This is probably the origin of the tumor.



Coronal CT of nose and sinuses showing smooth mass effect and mild rarefaction of posterior bony septum and medial maxillary wall.

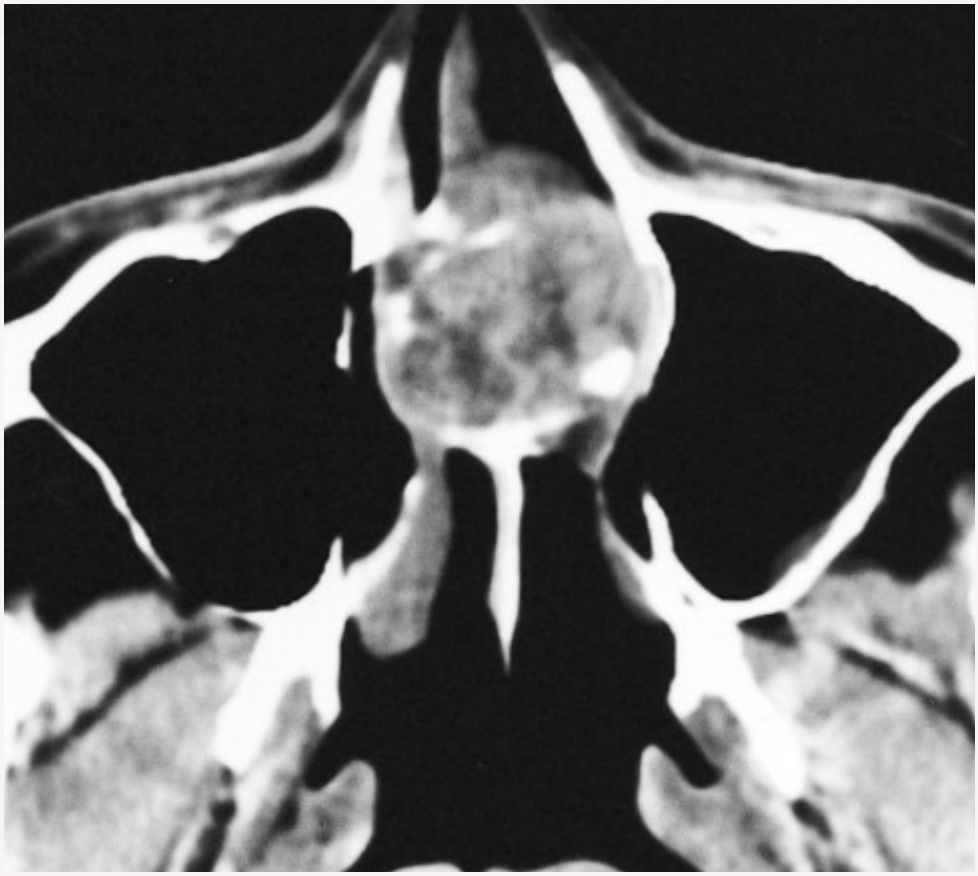
Axial CT showing papilloma arising from the left side of nasal septum

Nasal papilloma:

A typical nasal papilloma arises from nasal vestibule and is characterized by the epithelial proliferation growing in an exophytic manner.

Pleomorphic adenoma:

Pleomorphic adenoma of nose is a mixed tumor which commonly occurs in major salivary glands but are rare in nasal cavity. Majority of intranasal pleomorphic adenomas arise within the nasal cavity. Majority of pleomorphic adenomas occur betweeen the third and sixth decades of life and is seen more frequently in women. These patients present with a painless, unilateral nasal obstruction with a mass within the nasal cavity. Epistaxis could also be present. These tumors are polypoidal, sometimes smotth, lobular, firm. They are gray in color with a well defined capsule.



Contrast enhanced axial CT image showing intranasal mass. The mass has destroyed the nasal septum and occupies both nasal cavities. Maxillary sinuses are intact. The tumor shows heterogenous enhancement and contains small calcified foci. Features are suggestive of Pleomorphic adenoma.

Histologically, pleomorphic adenomas of the nasal cavity contain both mesenchymal and epithelial components. Although similar tumors are seen in major salivary glands the histopathologic features of mixed tumors of the nasal cavity differ in certain characteristics. Cellularity is usually greater in nasal cavity tumors than that seen in major salivary glands. Epithelial elements tends to predominate rather than stromal elements which is the case in pleomorphic adenoma involving major salivary glands.

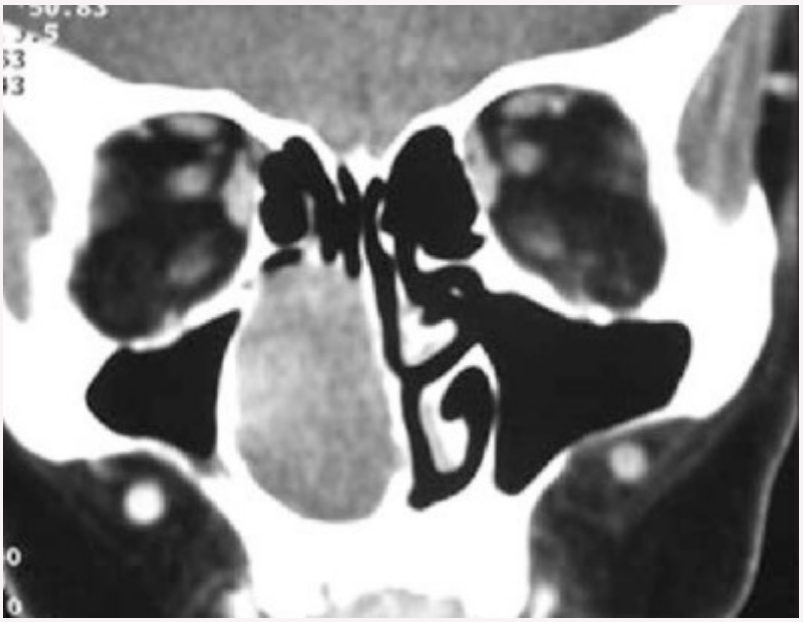


Image showing contrast enhanced lesion within right nasal cavity. The mass occupies major portion of right nasal cavity. Evidence of bone remodelling is also seen. Histopathology was reported as pleomorphic adenoma.

CT scan of nasal cavity, axial section showing homogenous spherical mass occupying anterior part of the right nasal cavity. Note: maxillary sinuses, posterior choanae and nasopharynx are clear. Histopathology revealed it to be pleomorphic adenoma.

Schwannomas:

These are benign and slow growing tumors originating from the schwann cells of peripheral nerve sheath. Schwannomas of sinonasal origin are rare. Main symptoms include:

1. Nasal obstruction

2. Headache

3. Facial pain

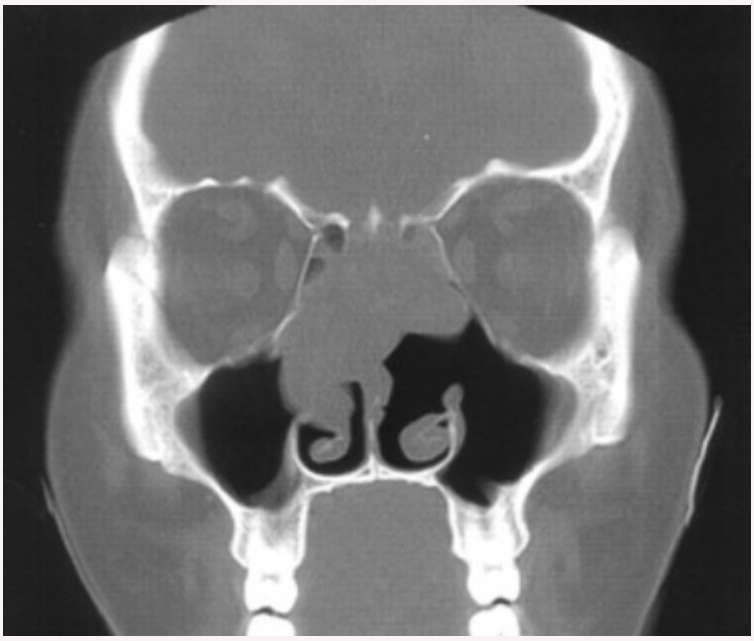
4. Anosmia

5. Intermittent bloody nasal discharge

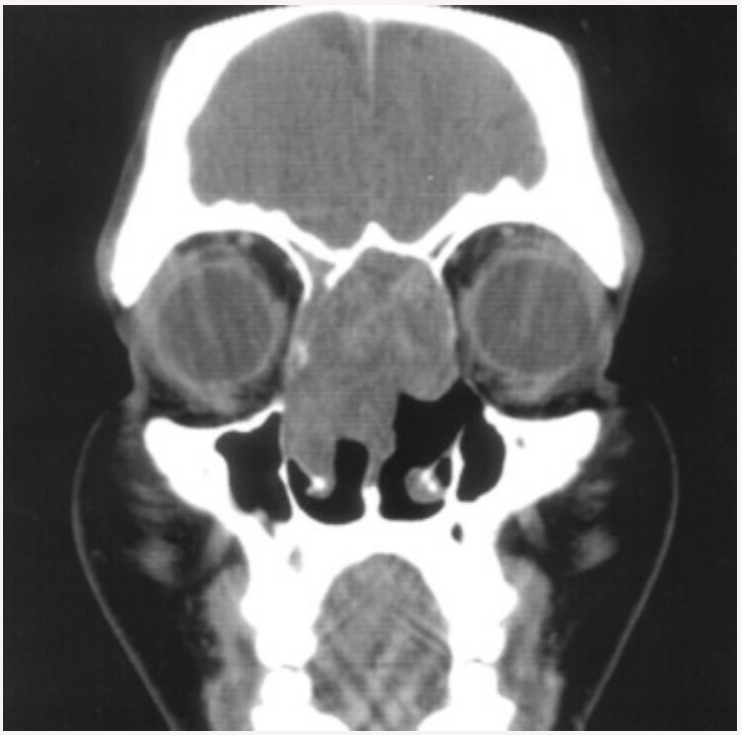
CT PNS would reveal a soft tissue mass expanding and remodeling the superior and inferior conchae and the medial wall of the maxillary sinus leading on to obstruction of the nasal cavity.

Usually schwannomas arise from large peripheral nerve fibers such as vestibulocochlear nerve, vagal nerve and cervical sympathetic trunk. Schwannomas of nasal cavity could arise from small somatosensorial nerve fibers of nasal septum (nasopalatine / nasociliary nerves). It can also arise from nasociliary and anterior ethmoid nerves.

Coronal CT of nose and sinuses showing soft tissue shadow occupying the entire right nasal cavity. Frontal sinus is also involved. Note remodeling of inferior and middle turbinate. Medial wall of maxillary sinus (R) could be seen bowing laterally into the sinus cavity reducing its volume. Biopsy turned out to be schwannoma.

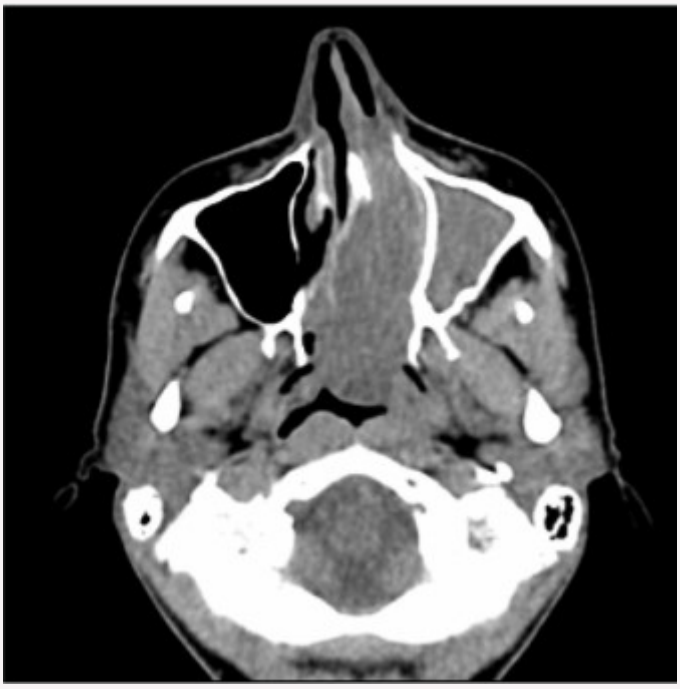


Coronal CT of nose and sinuses showing dehiscence of cribriform plate. Biopsy of the lesion turned out to be schwannoma.



Coronal CT image showing a mass lesion causing mild remodeling of the medial orbital wall and extension up to the level of cribriform plate. Biopsy of the lesion was reported as schwannoma.

Schwannomas arising from the nasal septum are usually small and round. Masses arising from nasal cavity and ethmoid sinus show a characteristic tubular shape along the anteroposterior / superoinferior axis of the nasal cavity. This resulted from the soft nature and slow growth pattern of the schwannoma without destruction and invasion of adjacent anatomic structures. Schwannomas of the nasal cavity might grow according to the alignment of the ethmoid lamellae and result in a tubular shape, extending anteroposteriorly or superoinferiorly. Tubular shape of the lesion could be helpful in differentiating schwannoma from other lesions inside the nasal cavity.



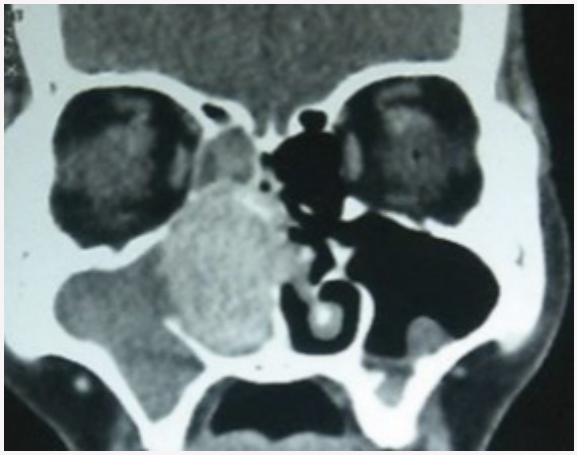
CT paranasal sinuses showing soft tissue shadow involving left nasal cavity. Note the presence of bone remodeling. Nasal septum is pushed to the opposite side. Bowing of the medial wall of left maxilla can be clearly made out. Haziness of left maxillary sinus could be due to pent up secretions due to obstruction to the natural ostium. Biopsy Report - Schwannoma.

Image showing soft tissue mass filling right maxillary sinus. Medial wall of maxilla is found to be pushed medially. Note the presence of bone remodeling. Biopsy was reported as Schwannoma.

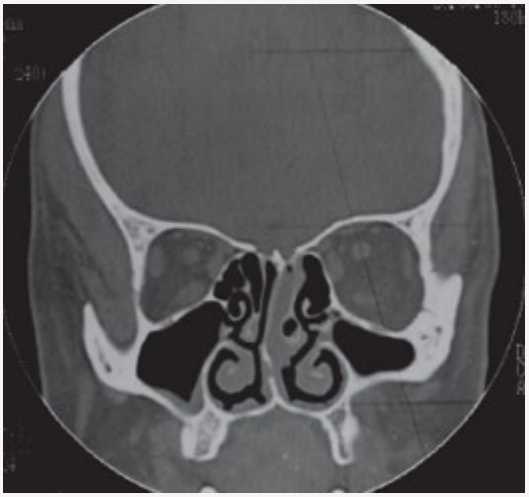
Meningiomas:

These are nonglial tumors of the central nervous system. They arise from the arachnoid cap cells (meningocytes) that are derived from the neural crest. These tumors have a predilection for females and have a bimodal age distribution with the first peak at the second decade of life. During embryogenesis, when arachnoidal cells that are present in the sheaths of nerves or vessels emerge through the skull foramina the then displaced Pacchionian bodies are detached / pinched off, or entrapped in an extracranial location. It can also occur following a traumatic event or cerebral hypertension that displaces the arachnoid islets, originated from undifferentiated or multipotent mesenchymal cells such as fibroblasts, schwann cells or a combination of these.

Nasal meningiomas are rare. They occur as a result of an extension of a primary intracranial mass. Some of these tumors can also be reported with no evidence of intracranial tumor. Once the diagnosis of meningioma has been established, the presence of a meningioma of the neuraxis or extension of a primary central menigioma should always be excluded. Recurrences usually develop in he same site as the primary lesion and could probably be the result of residual disease rather than recurrence.



CT of nose and sinuses showing heterogeneously enhancing mass in the right nasal cavity. The mass is centered in the middle turbinatewith extension in the middle turbinate with extension into the right ethmoid sinus superiorly. Nasal septum is destroyed with extension of the mass to the contralateral side. Biopsy of the lesion was reported as meningioma.



Coronal CT of nose and sinuses showing a veiling of nasal fossa ceiling between middle turbinate and nasal septum on the left side. Biopsy from the lesion was reported as Meningioma.

Primary extracranial meningiomas have been reported on the bones of the skull, orbit, temporal bone, inner ear, nasal cavity and paranasal sinuses. They are classified in to 4 different types:

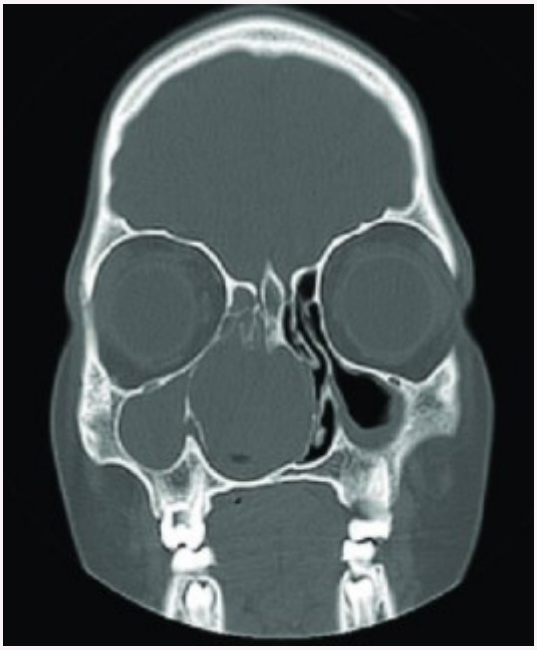
1. Extracranial extension of meningioma with intracranial origin

2. Extracranial extension of meningioma which arouse on neural foramen

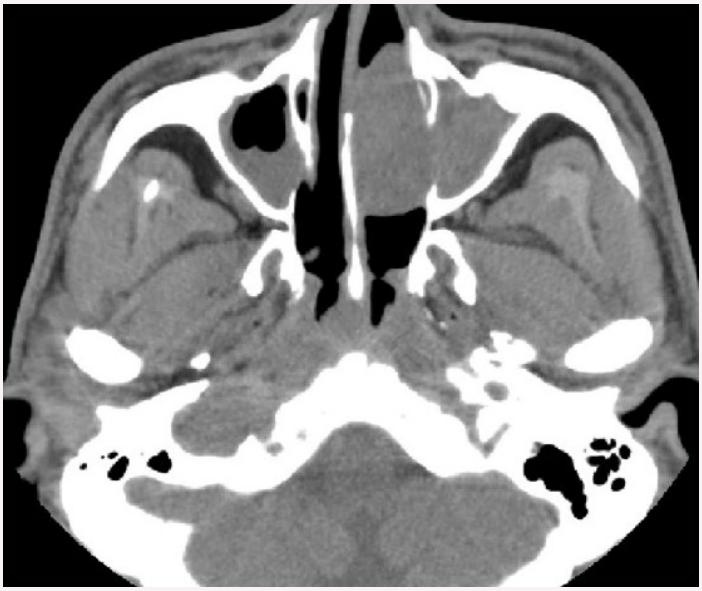
3. Primary and ectopic extracranial meningioma with no relation with foramen of cranial nerve or with endocranium

4. Extracranial metastasis of intracranial meningioma

Axial CT showing veiling effect over posterior ethmoidal cells and sphenoid sinus on the left side. Biopsy from the lesion was reported as meningioma.



Coronal CT showing soft tissue density lesion filling the right maxillary sinus, extending into the right nasal cavity causing widening of the ipsilateral osteomeatal complex and nasal cavity with left sided deviation of nasal septum. Lateral bowing of the medial wall of maxilla is to be noted.



Coronal CT PNS (Non contrast) showing soft tissue mass arising from nasal septum filling up the nasal cavity. It shows extension into the left maxillary antrum. Medial wall of left maxillary antrum is breached. Biopsy from the lesion was reported as Meningioma.

Hemangioma:

Hemangiomas are benign head and neck tumor and it constitutes about 20% of all benign nasal cavity tumors. Hemangiomas are known to occur commonly in the skin and mucous membrane. Exact etiology of these lesions are rather rare. Usually these lesions are solitary. In pediatric patients hemangiomas could be multifocal and are associated with a high risk of visceral (intra-hepatic) localization. These tumors are benign capillary proliferations with a distinctive lobular structure. Trauuma & hormonal factors are considered to be probable etiological factors. Sites inside the nasal cavity affected by hemangiomas include:

Anterior part of nasal septum (little's area) - commonest

Lateral wall

Intraosseous portion of inferior turbinate.

Septal hemangioma in pregnant women is considered to be a pregnancy related tumor.

Common problems associated with this tumor include:

1. Unilateral nasal obstruction (Progressive)

2. Epistaxis on and off

3. Mucopurulent discharge

4. Epiphora

5. Facial pain

6. Headache

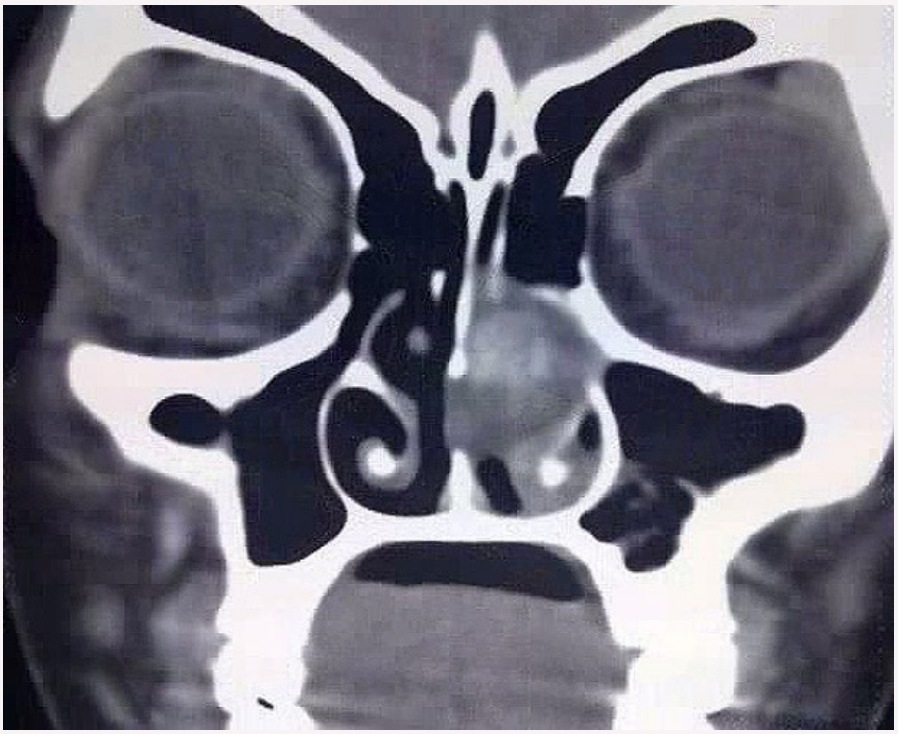
7. Hyposmia

Factors like oncogenic viruses, abnormal production of angiogenic growth factors, or cytogenic abnormalities could play a vital role in the development of these tumors. MUlliken classified hemangiomas into three subtypes:

Capillary hemangioma - Predominantly arising from anterior part of nasal septum (Little's area).

Cavernous hemangioma - Usually located in the lateral nasal wall

Mixed forms

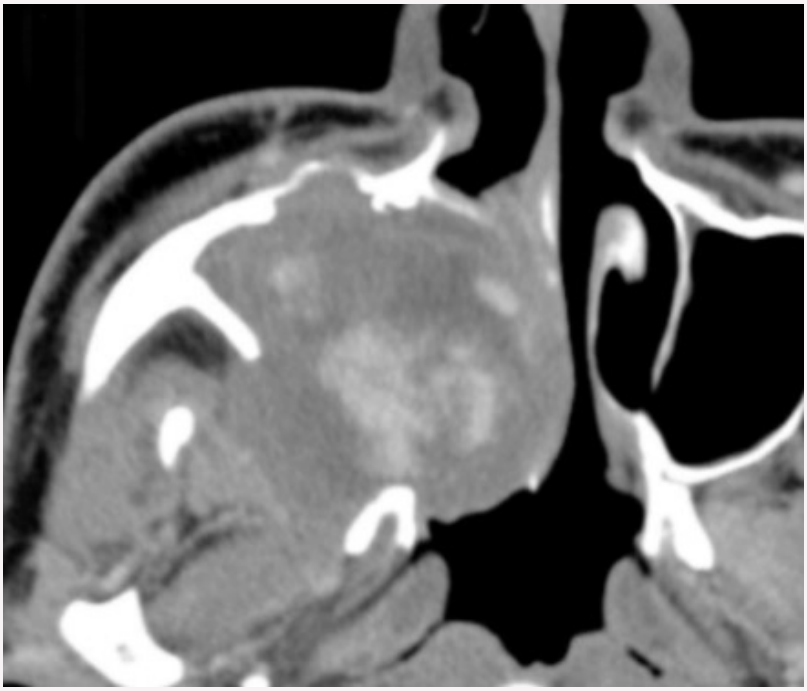


Coronal CT showing soft tissue mass arising from the anterior portion of nasal septum (Little's area) and expanding into the nasal cavity. This lesion would demonstrate enhancement in contrast CT images. Biopsy was diagnosed as Capillary hemangioma.

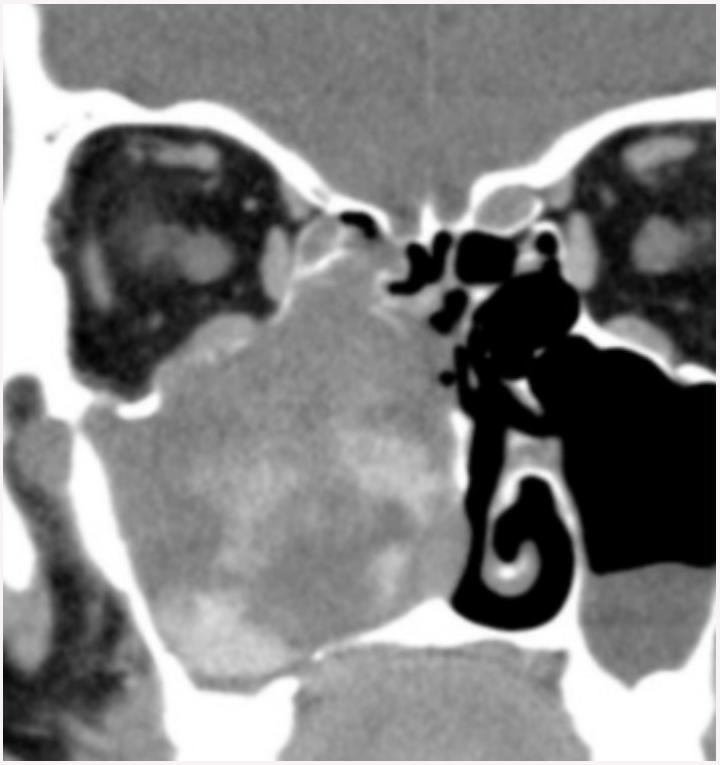
Axial contrast CT of nose and sinuses showing enhancing soft tissue mass filling the left maxillary sinus. The lesion is inhomogenous. There is evidence of focal bone remodeling of the anterior wall of the left maxillary sinus. Note patchy calcifications inside the mass.

These lesions could sometimes present as nonenhancing soft tissue masses in contrast CT. This could be due to necrosis and hemorrhage within the tumor. This scenario is more common in large lesions.

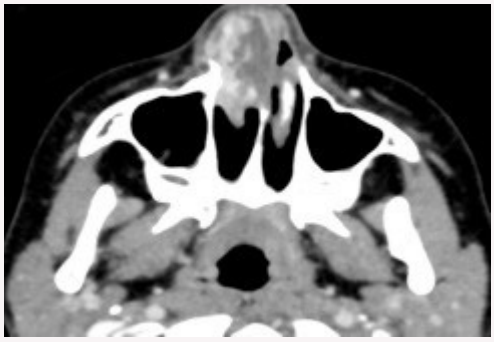
Hemangiomas have been reported to cause changes in adjacent bone. Capillary hemangiomas of nasal vault are known to produce benign appearing bone changes including remodeling / expansion. Curvilinear calcification seen in some patients is a non-specific finding, on the other hand phlebolith formation is a specific feature of cavernous hemangioma. Organised hematoma is the most difficult lesion to differentiate both clinically and radiologically from sinonasal cavernous hemangioma.



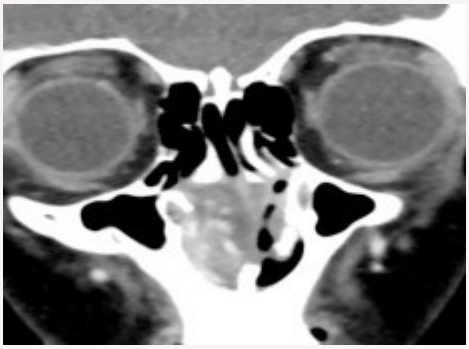
Axial CT nose and sinuses showing soft tissue density expansile lesion in the right maxillary antrum. Medial wall of maxilla is eroded and the same mass is occupying the entire nasal cavity. The mass is in contact with nasal septum. Biopsy of the lesion was reported as capillary hemangioma. Note patchy calcification within the mass.



Coronal CT of nose and sinuses showing expansile soft tissue lesion occupying right maxillary sinus with erosion of its medial wall. The same mass could be seen pushing the nasal septum to the opposite side. Note bone remodeling in inferior orbital wall and floor of maxillary sinus. Patchy calcification can be seen within the mass lesion.



Contrast axial CT of nose and sinuses reveal an intensely enhancing big vascular lesion with liquid content in the right nasal cavity (occupying the anterior area of middle and inferior meatus). There is no obvious bone remodeling / destruction. Biopsy was reported as cavernous heamngioma.

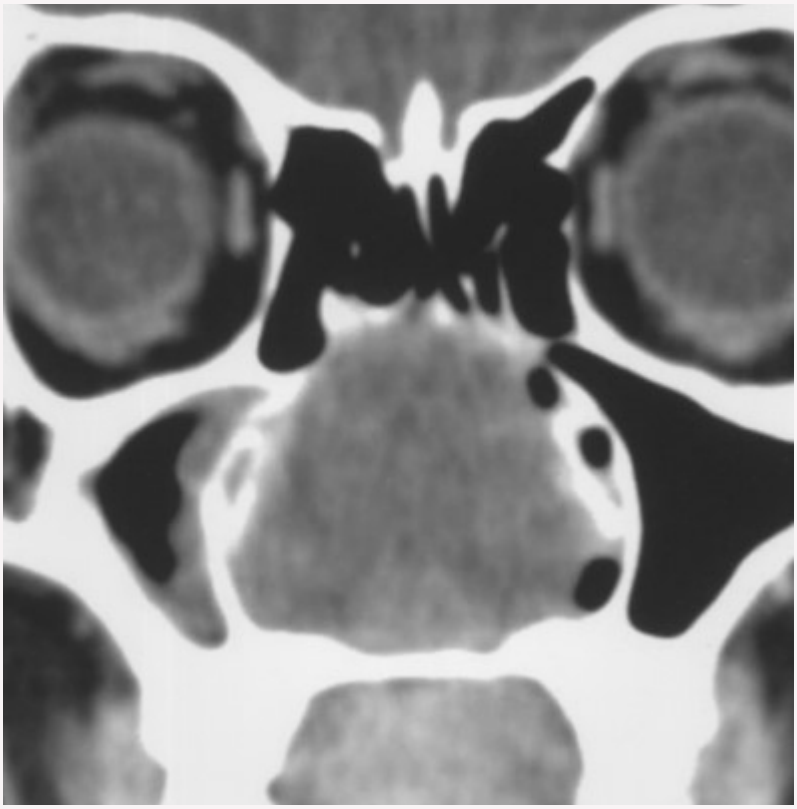


Coronal contrast CT of nose and sinuses showing enhancing soft tissue mass inside right nasal cavity pushing the nasal septum to the opposite side. Biopsy was reported as cavernous hemangioma. Note: The apparent erosion of nasal septum is due to partial averaging effect and is not a true one. This was evident when subsequent coronal cuts were studied.

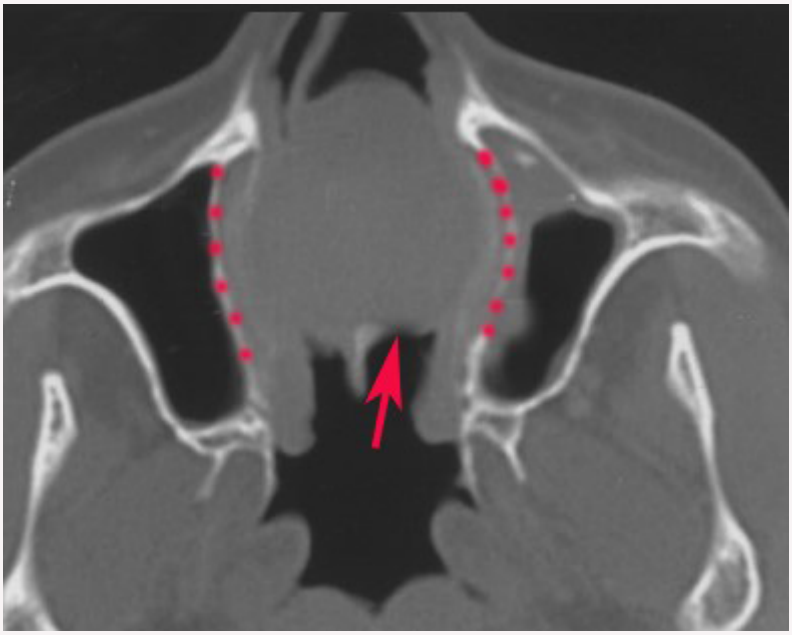
Lobular cavernous hemangioma is frequently seen in the anterior nasal septum. This is frequent in recurrent nose pickers or in patients with history of nasal packing. Local trauma could precede the genesis of lobular cavernous hemangioma.

Chondromas:

Chondrogenic tumors are relatively uncommon inside nasal cavity with malignancy occurring twice as frequently as in benign tumors. Histologic differentiation between chondroma and chondrosarcoma could be really difficult. Chondrogenic tumors involving the facial skeleton usually demonstrate aggressive behavior and hence these lesions should be considered to be potentially malignant.



Coronal CT of nose and sinuses showing contrast enhanced homogenous soft tissue mass arising probably from the nasal septum. Biopsy was reported as chrondroma.



Axial CT (bone window) showing soft tissue mass expanding the nasal cavity. Bowing of the nasal septum could be seen (pink arrow). Bowing of medial wall of maxillary sinus on both sides (pink dotted area). These findings are suggestive of slow growing neoplasm rather than malignant process. Note the absence of bony margin sclerosis. This is a notable feature in chondroma of nose.

Axial CT showing contrast enhancing soft tissue lesion on the right side of the posterior portion of nasal septum. Biopsy was reported as chondroma.

Juvenile nasopharyngal angiofibroma:

JNA are rare benign but locally aggressive vascular tumor that is known to occur exclusively in young men. Imaging would reveal enhancing soft tissue mass centered on the sphenopalatine foramen.

Theories of etiopathogenesis of JNA:

Ringertz theory: This theory was proposed by Ringertz in 1938. He believed that JNA always arose from the periosteum of the skull base.

Som & Neffson (1940): believed that inequalities in the growth of bones forming the skull base resulted in hypertrophy of the underlying periosteum in response to hormonal influence.

Bensch & Ewing (1941): thought that the tumor probably arose from embryoninc fibro cartilage between the basi occiput and basi sphenoid.

Brunner (1942): Suggested an origin from conjoined pharyngobasilar and buccopharyngeal fascia.

Marten et al (1948): Proposed a hormonal theory suggesting that these tumors resulted from deficiency of androgens or over activity of estrogens and that the hormonal stimulation is responsible for angiomatous components seen in JNA tissue.

Sternberg (1954): Proposed that JNA could be a type of haemangioma like a cutaneous haemangioma seen in children which regresses with age.

Osborn (1959): Considered two alternatives to explain the etiology of JNA. They proposed that the swelling could be due to either a hamartoma or residual fetal erectile tissue which were subject to hormonal influences.

Girgis & Fahmy (1973): Observed cell nests of undifferentiated epitheloid cells or "Zell ballen" at the growing edge of angiofibromas. This appearance was more or less similar to that of paraganglioma. They considered JNA to be a paraganglionoma.

The most accepted theory is that JNAs originate from sex steroid–stimulated hamartomatous tissue located in the turbinate cartilage. The proposed hormonal influence may explain why (rarely) some JNAs involute after puberty.

Pathophysiology: The proposed origin of the JNA is located along the posterior-lateral wall in the roof of the nasopharynx, usually in the region of the superior margin of the sphenopalatine foramen and the posterior aspect of the middle turbinate. Fetal histology confirms large areas of endothelial tissue in this region. Rather than invading surrounding tissue, this tumor displaces and distorts, relying on pressure necrosis to destroy and push through its bony confines. Intracranial extension is noted in 10-20% of cases.

JNA are seldom seen in children below the age of 8. The rate of growth of tumor and period of maximum development coincides with rate of erectile tissue of penis, both increasing in size

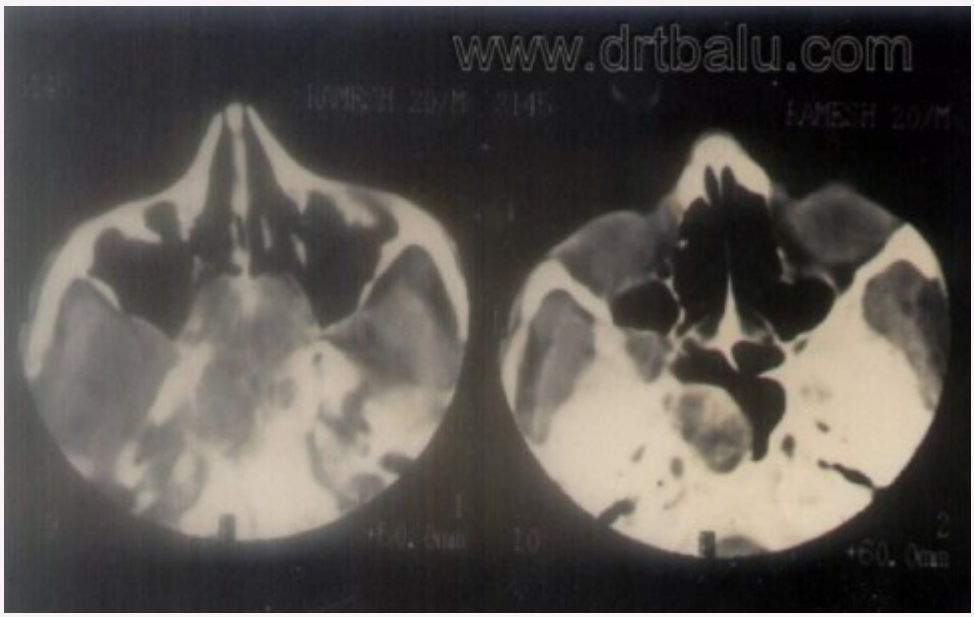
during the period of sexual development.

Clincial features: Signs and symptoms are present for an average of 6 months prior to the diagnosis, commonly with extension beyond the nasopharynx.
The two cardinal symptoms of angiofibroma are nasal obstruction and intermittent unprovoked epistaxis. Epistaxis may vary in severity from an occasional show to an alarming sometimes threatening torrent. Chronic anaemia is thus a feature of an established JNA.
The nasal obstruction is so complete causing stasis of secretions and sepsis become inevitable. Patients may even have hyposmia or anosmia.

The voice of the patient acquires a nasal intonation. If the swelling enlarges to force the soft palate down, the voice may become plummy.
Blockage of eustachean tube orifice is also common causing deafness and otalgia. Headache is not uncommon in long standing cases. If present it could be attributable to chronic sinusitis in some patients. Intracranial extension of the mass could also be the cause for headache in these patients.

Diplopia may occur secondary to the erosion of the mass into the cranial cavity and causing pressure on the optic chiasma. Failing vision has been attributed by Shaheen to the tenting of the optic nerveby the tumor.

Anterior rhinoscopy shows the presence of abundant purulent nasal secretions together with bowing of nasal septum to the uninvolved side. Posterior rhinosocpy in a cooperative patient shows a pink or red mass filling the nasopharynx. Due to the bulk of the lesion it may not be always possible to ascertain the site of origin accurately.



Axial CT showing contrast enhancing lesion occupying nasopharynx and sphenoid sinus

Imaging plays an important role in diagnosis and staging. Biospies should be avoided due to the risk of bleeding. Even though these masses are thought to arise from the region of sphenopalatine foramen, they are usually sizable at diagnosis, frequently with extension medially into the nasopharynx, laterally into the pterygopalatine fossa, and sometimes into the orbit and paranasal sinuses. In extreme cases intracranial extension can also be seen.

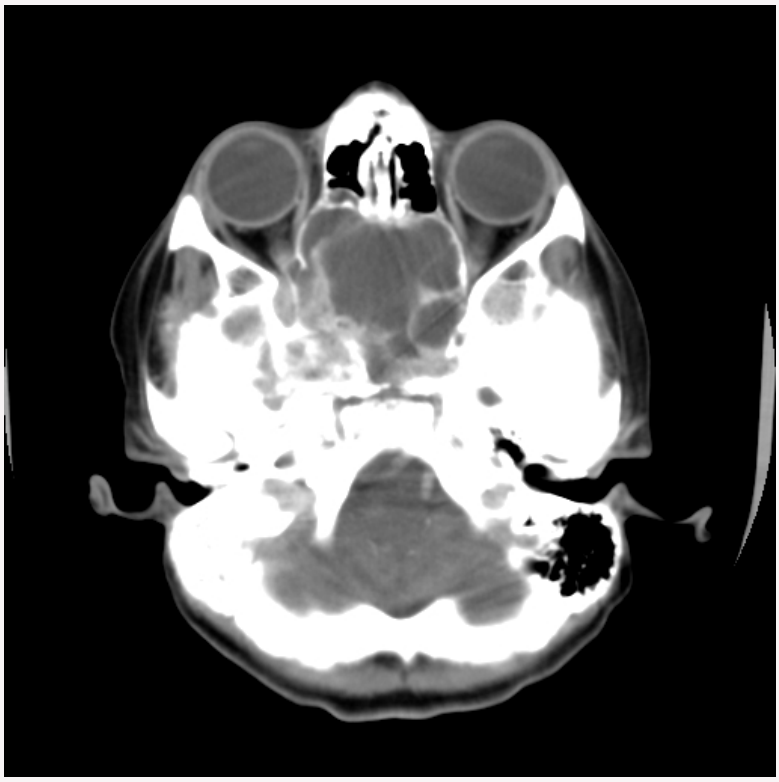
CT is useful:

1. In assessing the extent of the lesion

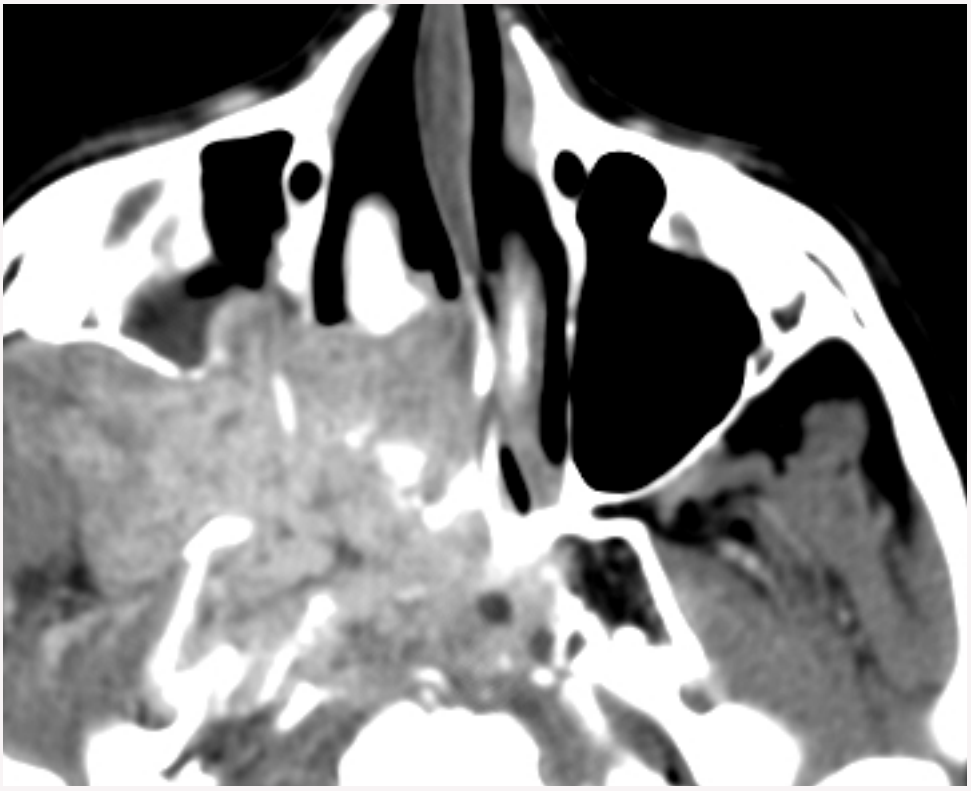
2. In delineating bony changes

3. Marked contrast enhancement following administration of contrast reflecting prominent vascularity

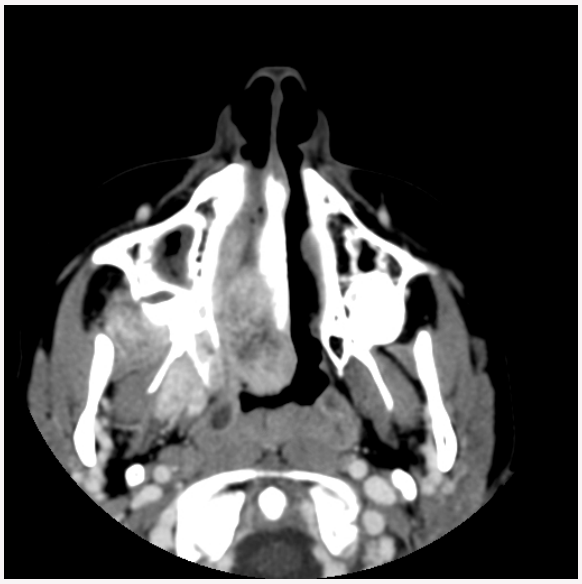
Extensive bony destruction is usually not a classic feature. On the other hand bone gets remodeled / resorbed. This feature could help in the differentiation of this lesion from other aggressive malignant lesions.



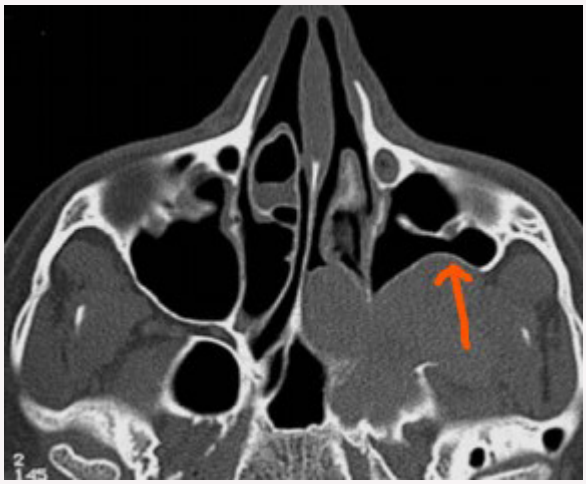
Contrast axial CT showing contrast enhancing soft tissue mass occupying the entire nasopharynx and the posterior portion of nasal cavity. Note tenting of optic nerve by the mass on the left side. (Suspected JNA lesion).



Axial CT (contrast) showing enhancing soft tissue lesion involving nasopharynx, posterior nasal cavity and pterygopalatine fossa. Note bowing of posterior wall of right maxillary antrum Holman Miller sign. Probable diagnosis (JNA)



Axial CT contrast showing enhancing soft tissue mass occupying the entire right nasal cavity extending up to the nasopharynx. Medial wall of right maxillary sinus shows bowing effect.



Axial CT showing contrast enhancing soft tissue mass occupying the posterior portion of the nasal cavity extending to the nasopharynx and pterygopalatine fossa. Note the bowing of posterior wall of left maxillary sinus (orange arrow). This is known as Holmen Miller sign. Presence of this sign indicates that the mass has involved pterygopalatine fossa.

Tumors of bone and cartilage:

A vaiety of benign neoplasms and fibro-osseous lesions arise from the bones and cartilages of the nose and sinuses. The term fibro-osseous which is used to indicate these conditions refers to a category of benign neoplasms or tumor like lesions with osteoma, ossifying fibroma and fibrous dysplasia. Fibrous dysplasia is a non-neoplastic tumor like condition.

Osteomas:

These are most common neoplasms of the sinuses and are usually found in the frontal and ethmoid sinuses. Their incidence being 1-3% of the population. These patients remain largely asymptomatic. Osteomas are more common in men (in fact twice as common than in women). It remains mostly as incidental findings in patients over the age of 50. Multiple osteomas could be seen as a component of Gardner's syndrome which include colorectal polyposis.

Osteomas coud become symptomatic in one of the two ways:

1. Direct mass effect

2. Obstruction of normal sinus drainage

Pain due to osteoma can be caused by:

Local effect

Referred pain via trigeminal nerve

Prostaglandin E-2 mediated mechanism.

Some osteomas are large and exophytic. Rarely an osteoma could encroach upon the brain and could even result in erosion of the dura with resultant CSF leak. Frequently osteomas could impair normal drainage of one or more paranasal sinuses, thereby resulting in acute/chronic sinusitis or even mucocele formation.

As far as nose and sinuses are concerned osteomas are commonly seen in:

Frontal sinuses - 80%

Ethmoid air cells - 15%

Maxillary sinus - 5%

Sphenoid sinus - Very rare

Subtypes:

Three histological patterns of osteomas are recognized:

1. Ivory osteoma

This is also known as eburnated osteoma.

This is the most common type encountered.

This is a dense bone lacking Haversian system.

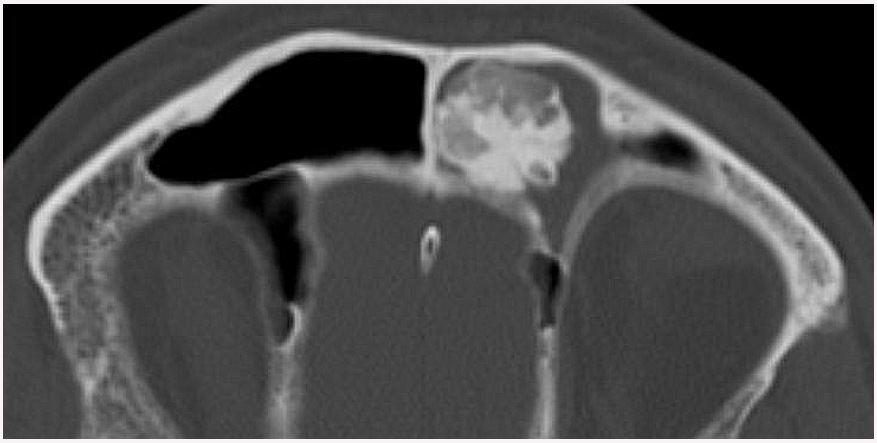
2. Mature osteoma

This is also known as osteoma spongiosum

This resembles normal bone, including trabecular bone with bone marrow.

3. Mixed osteoma

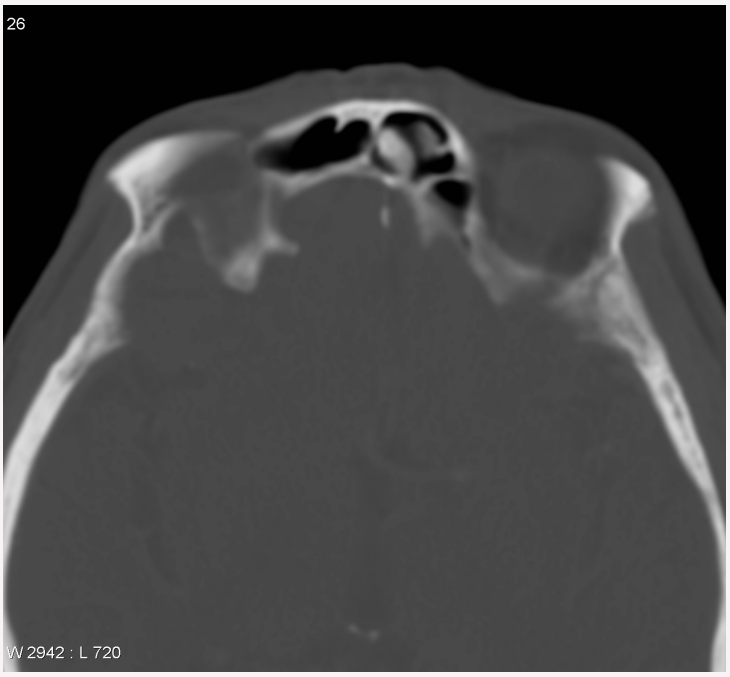
This variety is a mixture of ivory and mature osteology



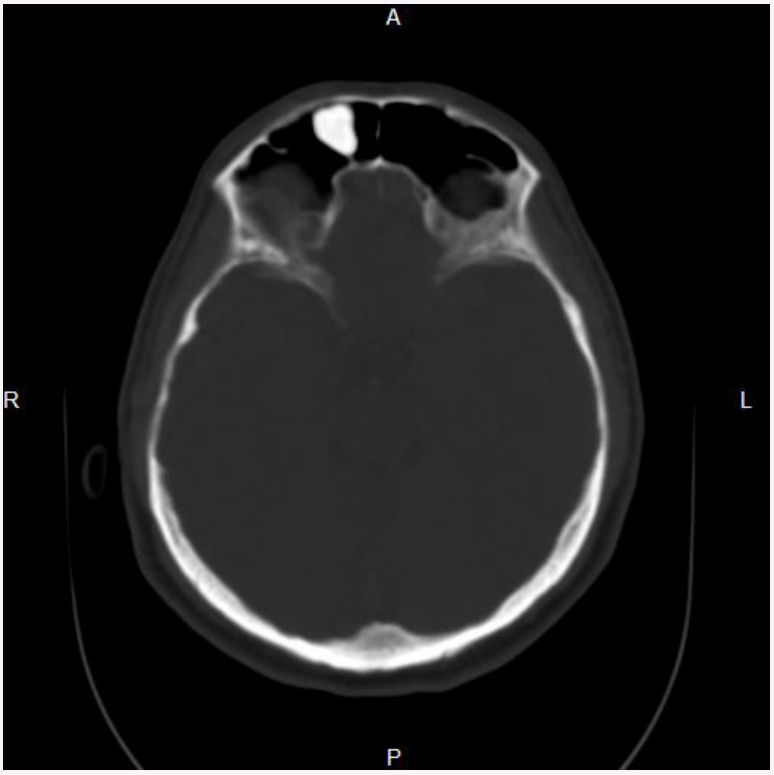
Axial scan bone window showing osteoma inside left frontal sinus cavity.

CT scan:

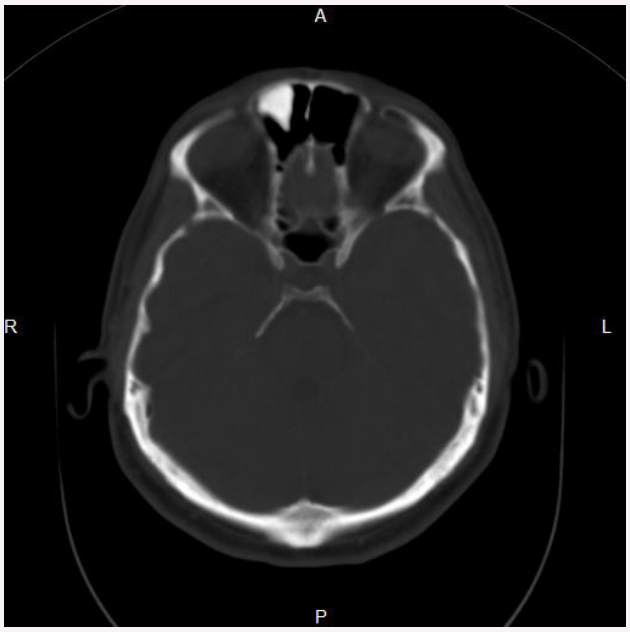
Patients with osteoma would demonstrate well circumscribed mass of varying density, varying form very dense to normal cortical bone to less dense with a ground glass appearance.



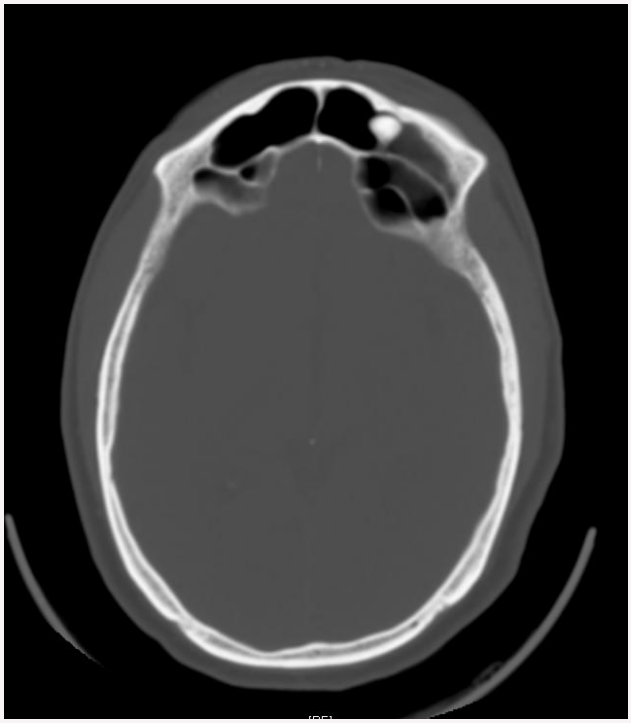
Axial CT bone window showing osteomas within left frontal sinus



Axial CT bone window showing densely radio opaque osteoma within right frontal sinus. Probably ivory osteoma. In this condition the mass is highly dense.



Axial CT bone window showing dense radio opaque mass within right frontal sinus. The mass is seen attached to the anterior wall of frontal sinus.



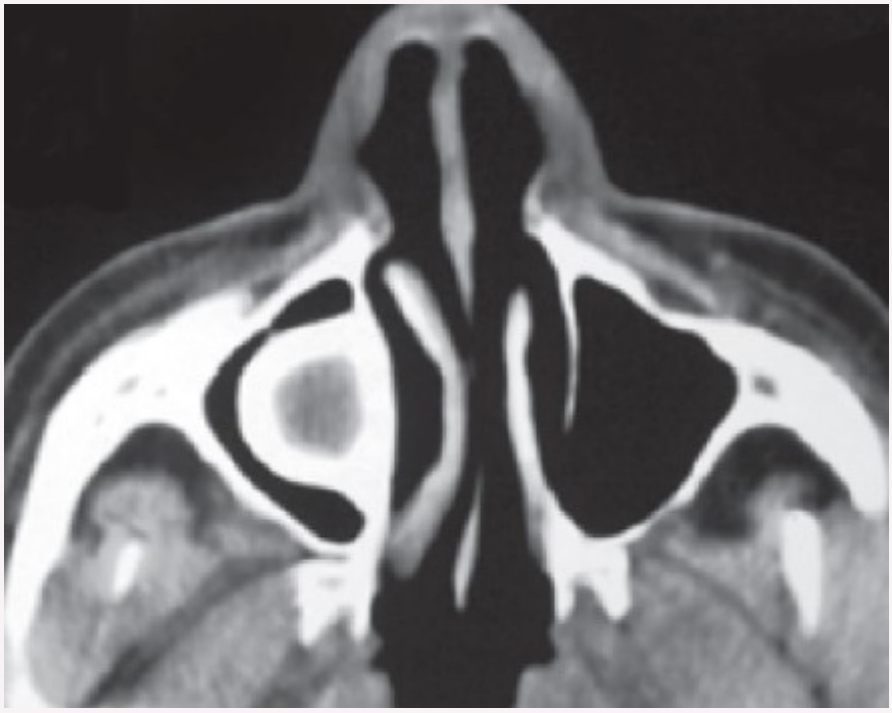
Axial CT bone window showing pedunculated osteoma inside left frontal sinus. Note the pedicle is attached to the posterior table of frontal sinus

Axial CT bone window showing osteoma involving left ethmoid sinus

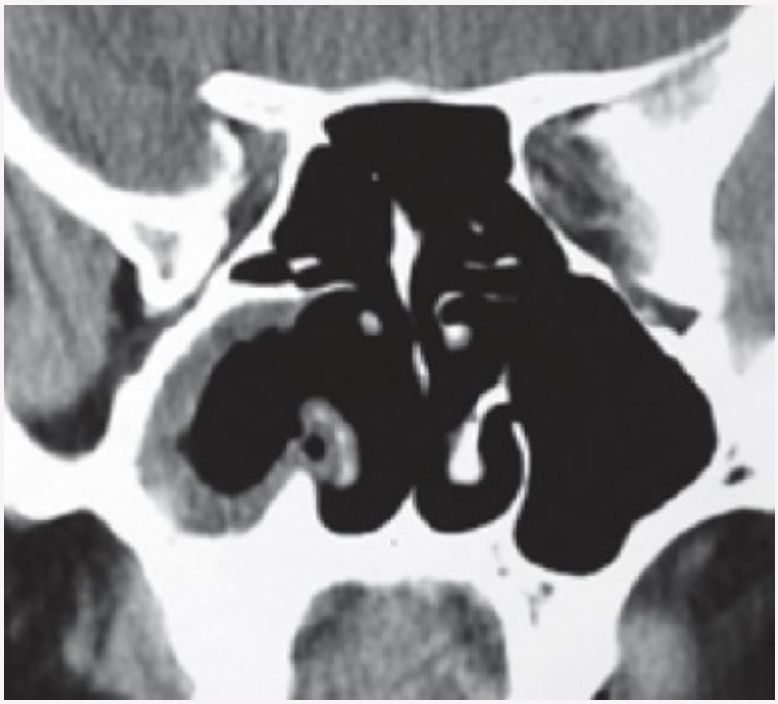
Axial CT bone window showing radio dense lesion within left frontal and ethmoidal sinuses. Probable diagnosis Osteoma involving frontal and ethmoidal sinuses.

Coronal CT sinuses showing osteoma in the left frontal sinus causing obstruction to frontal outflow tract

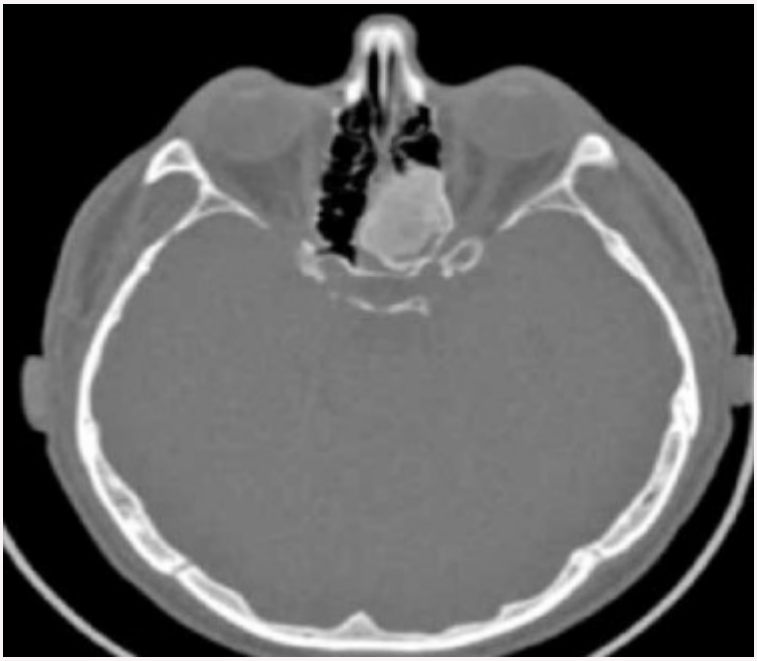
Coronal CT of nose and sinuses showing osteoma involving the anterior ethmoid group of sinuses.



Axial CT image showing osteoma involving right maxillary sinus. Osteoma could be seen attached to the medial wall of maxilla.



Coronal CT post operative image showing resultant maxillary sinus after complete removal of osteoma from right maxillary sinus



Axial CT showing radio dense mass occupying the sphenoid sinus. Probable diagnosis is osteoma of sphenoid sinus

Axial CT showing osteoma involving posterior ethmoid group of sinuses (left side).

Fibrous dysplasia:

Fibrous dysplasia is a benign slow growing fibro-osseous disease characterized by replacement of normal bone with varying degrees of fibrous tissue / immature woven bone. This was first described by Lichtenstein in 19381 who called it "perverted activity of bone forming mesenchyme".

Classification of fibrous dysplasia:

1. Monostotic variety – Involving single bone
2. Polyostotic variety – Involving multiple bones
3. McCune-Albright syndrome – Characterized by polyostotic fibrous dysplasia in association with hyperfunctional endocrinopathies (precocious puberty, hyperthyroidism, or acromegaly) and cafe au lait spots involving the skin.

Classic epidemiological features of this disorder include:

1. It accounts for about 10% of all bony tumors
2. Monostotic variety is ten times more prevalent than polyostotic variety

3. Majority of monostotic fibrous dysplasia manifest during the first three decades of life
4. Polyostotic fibrous dysplasia presents early during childhood
5. McCune-Albright syndrome also manifests during early childhood.
6. Among facial bones commonest to be involved is ethmoid, followed by frontal and maxilla.

Pathophysiology:
Intramedullary lesions grossly appear as well circumscribed tumors varying greatly in size. Large intramedullary lesions tend to cause bone expansion and distortion.

Microscopic appearance: These lesions appear as irregular trabeculae of woven immature bone.

They resemble Chinese characters. These lesions are surrounded by normal bone and covered by cellular fibrous stroma with osteoblast progenitor cells closely resembling fibroblasts.

In fibrous dysplasia bone marrow stromal cell differentiation is arrested. This leads to proliferation of immature cells causing the characteristic fibrous dysplasia. The exact molecular etiology causing this problem has been identified as somatic missense mutation involving GNAS 1 gene on chromosome 20. This
gene is responsible for encoding ά subunit of stimulatory G protein coupled receptor Gs ά. In fibrous dysplasia cells arginine is replaced by either cysteine / histidine. This results in inhibition of intrinsic GTPase activity of Gs ά protein. This causes independent activation and accumulation of Cyclic AMP.
In bone this causes an effect similar to that of continuous parathormone stimulation. Growth of fibrous dysplasia is enhanced in the presence of growth stimulating hormones. Growth rate of fibrous dysplasia decreases with age as the growth stimulating hormone levels decrease.

Clinical features of fibrous dysplasia:

Clinical features are largely dependent on compression of adjacent structures.

1. Asymptomatic painless bony enlargement causing deformity and asymmetry
2. Headache
3. Blurring of vision
4. Visual field defects
5. Diplopia
6. Hearing loss
7. Epiphora
8. Eyelid position abnormalities

Non skeletal manifestations of Fibrous dysplasia:

1. Abnormal cutaneous pigmentation (Jagged “coast of Maine” border
2. Precocious puberty
3. Hyperthyroidism
4. Cushing’s disease
5. Hyperparathyroidism

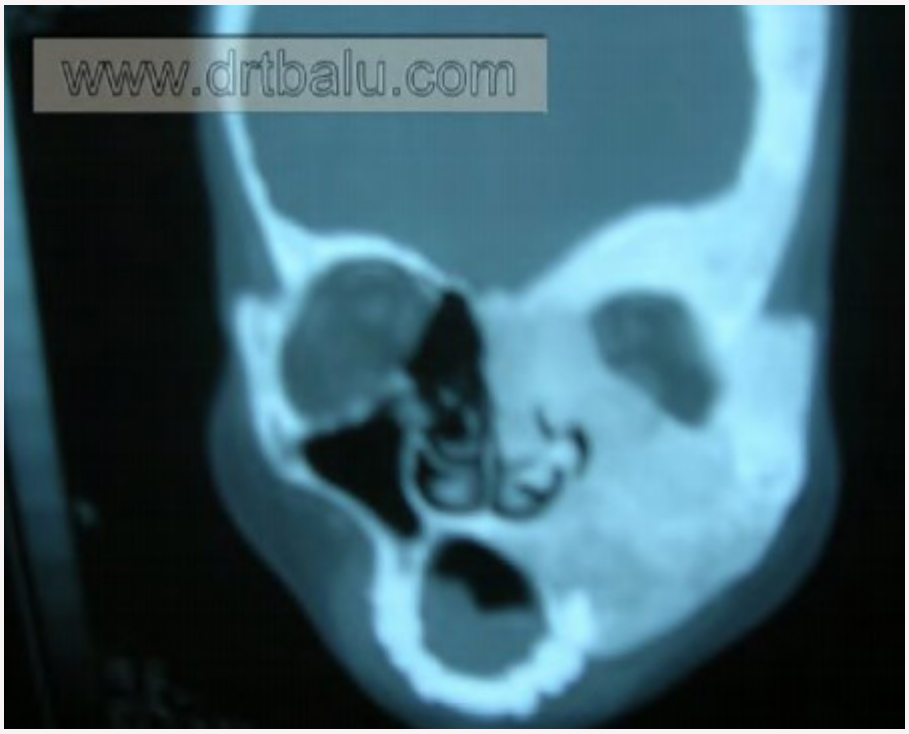
6. Hypophosphatemic rickets

Role of radiology in the diagnosis of fibrous dysplasia:
Majority of fibrous dysplasia are asymptomatic but for the asymmetry caused by the lesion. Since these tumors are very slow growing ones, it could take a long time before the effects of neurovascular compression begin to take place.

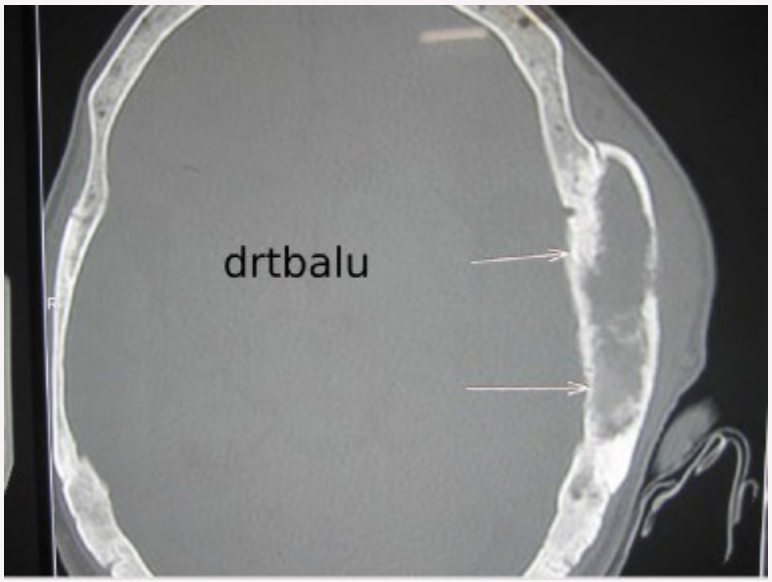
Radiological diagnosis alone would suffice for all patients with monostotic fibrous dysplasia. But polyostotic fibrous dysplastic lesions should always be biopsied for histopathological correlation.

CT appearance of fibrous dysplasia:

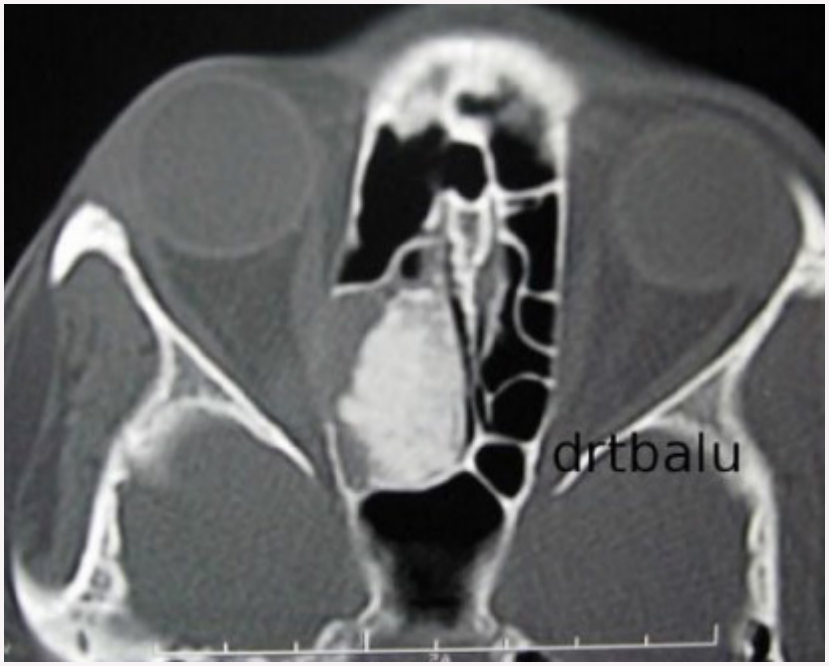
Commonly the lesion appears like ground glass – 50-60%
Homogenous dense pattern – seen in 20-30%
Cystic pattern – Seen in 10-20% of cases



CT coronal cut of nose and paranasal sinuses showing fibrous dysplasia of left maxilla. This is the classic homogenous dense pattern



CT scan showing fibrous dysplasia of zygoma



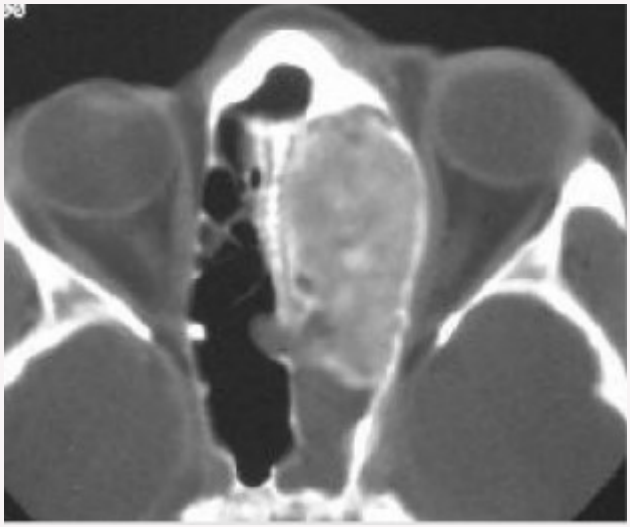
Axial CT showing fibrous dysplasia involving posterior ethmoid cells (ground glass type) on the right side. Note the lesion is seen compressing the right optic nerve

Chen & Noordoff classification 20 of craniofacial fibrous dysplasia:

1. Zone I : Fibrous dysplasia involving fronto orbital, zygomatic and upper portions of maxilla
2. Zone II: Fibrous dysplasia involving cranium (in its hair bearing area)
3. Zone III: Fibrous dysplasia involving the central portion of skull base
4. Zone IV: Fibrous dysplasia involving teeth bearing regions of maxilla and mandible.

This classification helps in deciding the management modality.

Coronal CT showing features of Zone IV fibrous dysplasia

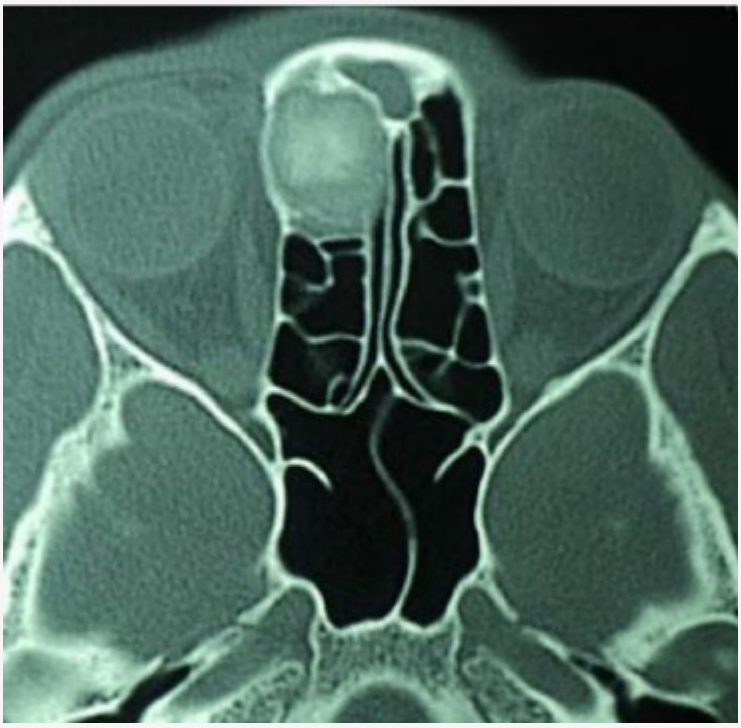


Axial CT showing fibrous dysplasia of ethmoids (Note ground glass appearance)

Coronal CT image showing fibrous dysplasia of ethmoid with attachment to skull base

Coronal CT showing fibrous dysplasia of orbit with involvement of skull base

Axial CT of nose and sinuses showing fibrous dysplasia involving anterior ethmoid.



Axial CT of nose and sinuses showing fibrous dysplasia involving anterior ethmoid.

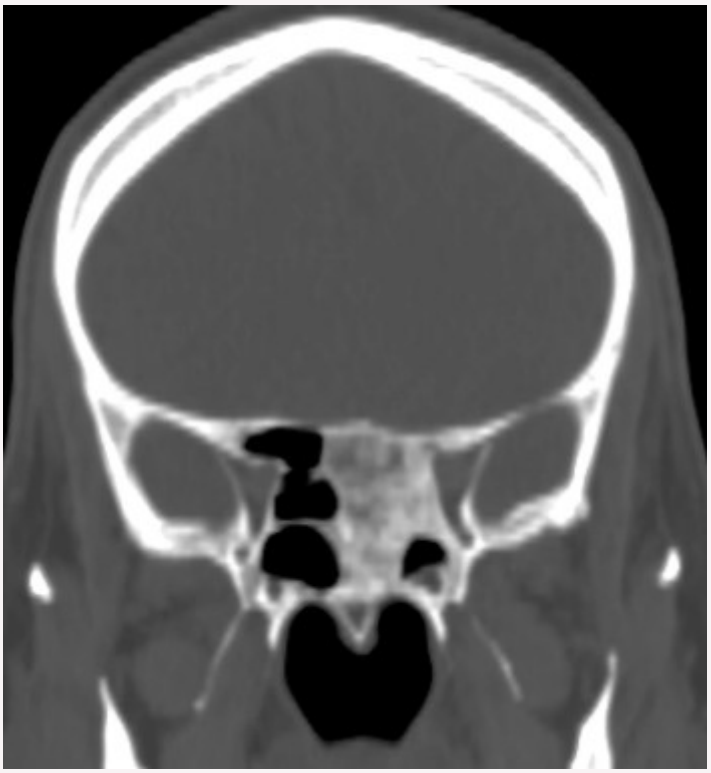
Coronal CT image showing fibrous dysplasia involving anterior ethmoid ex tending into the orbit. Not frontal sinus drainage area is compromised

Axial CT nose and sinuses showing a well defined ground glass bony lesion with sclerotic borders occupying the right nasal cavity extending into right orbital cavity and maxillary sinus causing nasal septal deviation to the opposite side.

Axial CT of nose and sinuses showing fibrous dyplasia lesion arising from middle turbinate on the right side. If these lesions could be picked up this early then excision of turbinate alone will solve the problem.

Axial CT bone window showing well circumscribed bony dense lesion occupying right nasal cavity obliterating middle turbinate architecture.

Coronal CT bone window nose and sinuses showing extensive expansile lesion of the left maxilla (ground glass appearance). The left maxillary sinus is small and is displaced posteromedially.



Fibrous dysplasia seen involving sphenoid sinus. Note ground glass opacity in the sphenoid sinus region with sclerotic rim involving the skull base causing regional mass effect, obliterating both sphenoid sinuses causing indentation of the left optic canal.

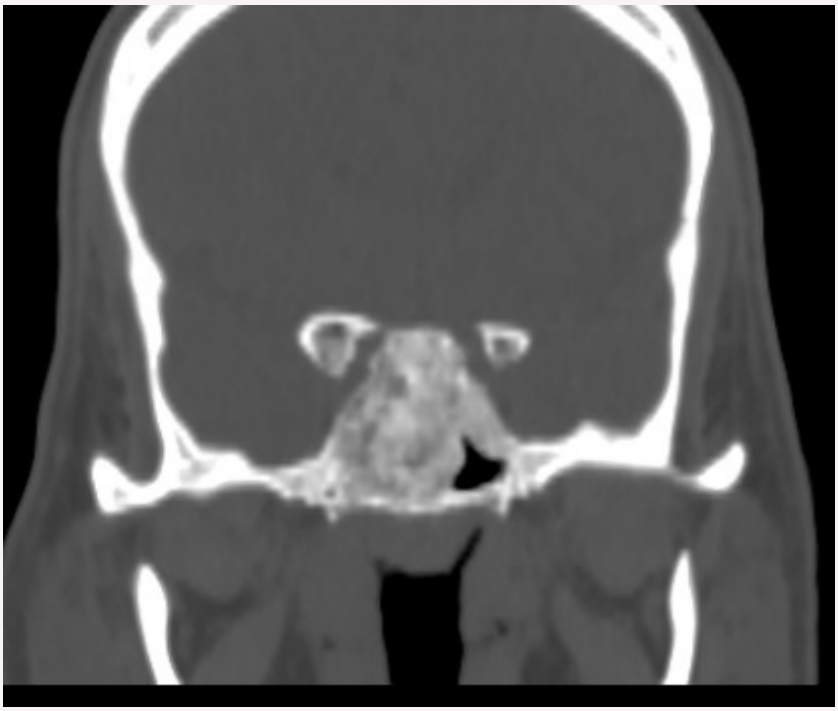


Image showing fibrous dysplasia occupying major portion of sphenoid sinus. Note ground glass appearance of the lesion

Role of Imaging in Faciomaxillary trauma

Imaging plays a vital role in assessment of the severity of Faciomaxillary trauma. Properly performed CT imaging reveals not only the exact fracture site but also helps the surgeon in deciding the optimal management modality.

The entire facial skeleton is supported by two buttresses, one horizontal andone vertical. These buttresses play an important role in absorbing deforming forces of injury.

The buttress system of midface is formed by strong frontal, maxillary, zygomatic and sphenoid bones and their attachments to one another. The central midface contains many fragile bones that could easily crumble when subjected to strong forces. These fragile bones are surrounded by thicker bones of the facial buttress system lending it some strength and stability. Components
of Buttress system:

For better understanding the components of the facial buttress system have been divided into:

1. Vertical buttresses
2. Horizontal buttresses

Vertical buttress: These buttresses are very well developed.
They include:

1. Nasomaxillary
2. Zygomaticomaxillay
3. Pterygomaxillay
4. Vertical mandible

Majority of the forces absorbed by midface are masticatory in nature. Hence the vertical buttresses are well developed in humans.

Horizontal buttresses:

These buttresses interconnect and provide support for the vertical buttresses. They include:

1. Frontal bar
2. Infraorbital rim & nasal bones
3. Hard palate & maxillary alveolus

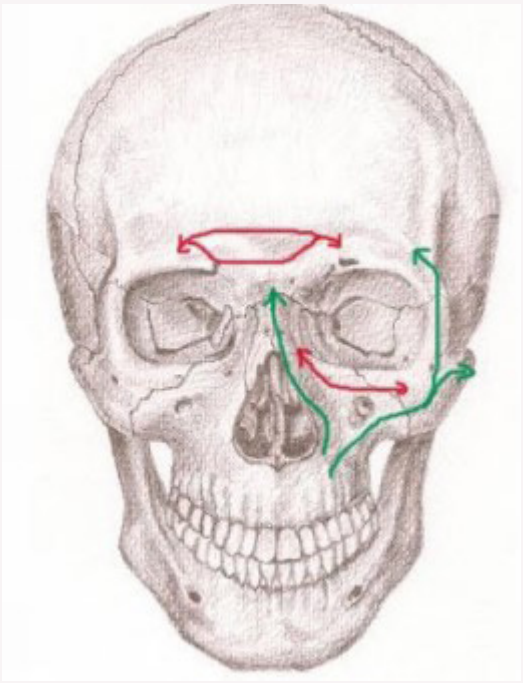
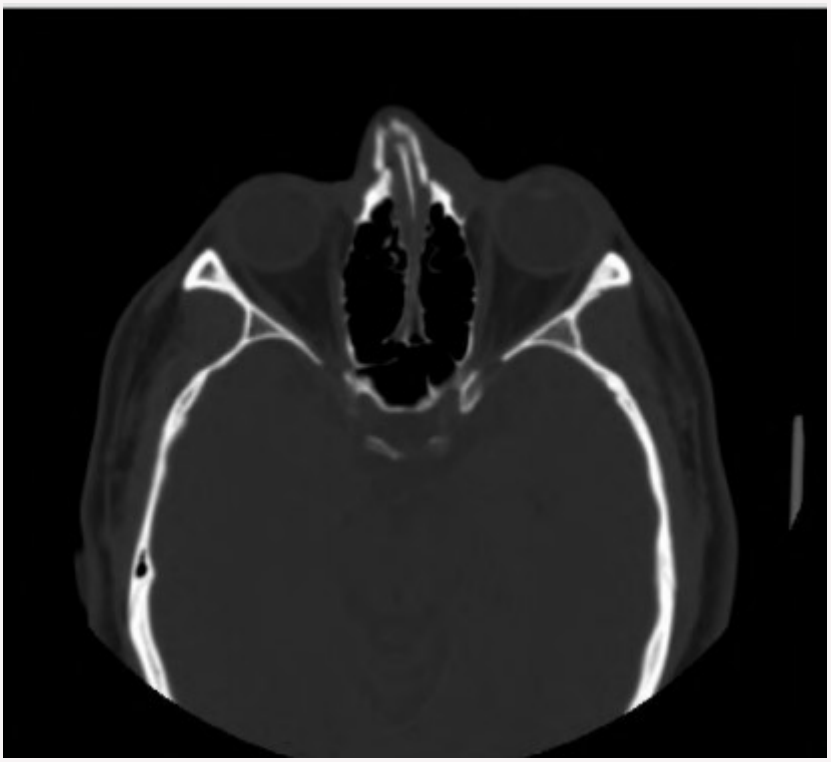


Image showing various buttresses of midface

Fracture nasal bones:

Nose is the most prominent part of the face, hence it is likely to be the most common structure to be injured in the face. Although fractures involving the nasal bones are very common, it is often ignored by the patient. Patients with fractures of nasal bone will have deformity, tenderness, hemorrhage, edema, ecchymosis, instability, and crepitation. These features may be present in varying combinations.



Axial CT of nose and sinuses showing fracture of both nasal bones

Nasal bone fractures are common because:

1. Nose happens to be the most prominent portion of the face
2. Increasing number of road traffic accidents
3. Increasing incidence of domestic violence
4. Increase in the number of individuals taking part in contact sports

Nasal bones are paired bones. Both these bones project like a tent on the frontal process of maxilla. In the midline they articulate with one another. Just under this midline articulation lies the nasal septum. Superiorly the nasal bones are thicker where it articulates with the nasal process of frontal bone.

This area is relatively stable and firm. Nasal bone fractures commonly occur at the transition zone between the proximal thicker and distal thinner portions. This zone precisely corresponds to the lower third of the nasal bone area. Fractures involving nasal bones if not properly and promptly treated leads to:

1. Nasal deformities

2. Intranasal dysfunction like nasal block

Fracture nasal bone is known to cause higher incidence of morbidity and complications when compared that of fractures involving other facial bones. In order to treat this condition properly it is necessary to accurately diagnose this condition by:

1. Looking for crepitus and tenderness over the nasal bone area
2. Radiographic evaluation of nasal bones. Radiography helps in diagnosis
and classification of nasal bone fractures, and also in checking the adequacyof reduction.

Pathophysiology:

The following points should be borne in mind before attempting to understand the pathophysiological factors that lead to fractures involving nasalbones.

1. Nasal bones and underlying cartilage are susceptible for fracture becauseof their more prominent and central position in the face.
2. These structures are also pretty brittle and poorly withstands force of impact.
3. The ease with which the nose is broken may help protect the integrity ofthe neck, eyes, and brain. Thus it acts as a protective mechanism.
4. Nasal fractures occur in one of two main patterns- from a lateral impact orfrom a head on impact. In lateral trauma, the nose is displaced away from the midline on the side of the injury, in head-on trauma, the nasal bones are pushed up and splayed so that the upper nose (bridge) appears broad, but the height of the nose is collapsed (saddle-nose deformity). In both cases, the septum is often fractured and displaced.
5. The nasal bone is composed of two parts: A thick superior portion and a thin inferior portion. The intercanthal line demarcates these two portions. Fractures commonly occur below this line.
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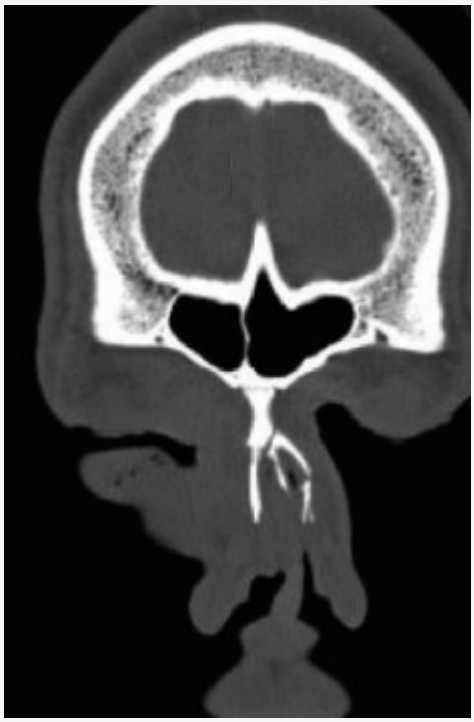
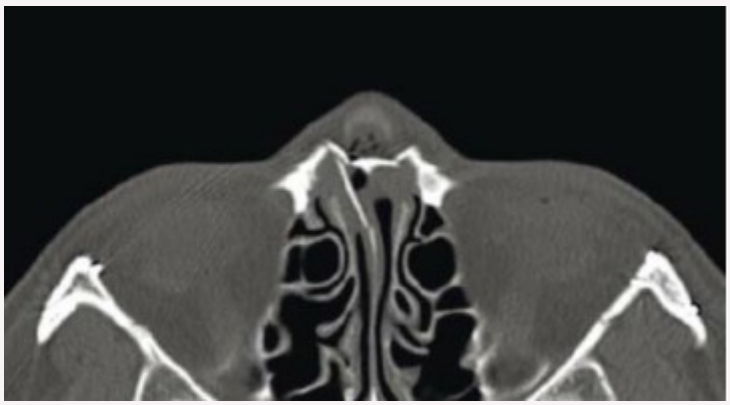
6. Nasal bones undergo fracture in its lower portion and seldom the upper portion is involved in the fracture line. This is because the upper portions of the nasal bone is supported by its articulation with the frontal bone and frontal process of maxilla.
7. Because of the close association between nasal bone and the cartilaginous portions of the nose, and the nasal septum it is quite unusual for pure nasal bone fractures to occur without affecting these structures. If closed reduction alone is performed to reduce nasal bone fractures without correction of nasal septal fractures, this could cause progressive nasal obstruction due to uncorrected deviation of nasal septum. This is because of the tendency of the nasal septum to heal by fibrosis which causes bizarre deviations like “C” “S” etc. Since nose is the most prominent portion of the face, its supporting bony structures have low breaking strength the naso ethmoidal complex frac tures when exposed to forces of about 80 grams. This fact was demonstrated by Swearinger in 1965.

Axial CT of nose and sinuses showing buckling of nasal septum due to fracture involving nasal bones

Axial CT showing fracture of right nasal bone with distortion of nasal pyramid and deviation of the tip of the nose to the opposite side.



Coronal CT bone window showing fracture with displacement of left nasal bone. Note the fractured fragments of bone are not in alignment. The pyramidal contour of nasal pyramid is distorted.



Axial CT showing depressed fracture of nasal bone with impaction of middle segment. Note bony segment of nasal bone is also fractured and deviated to the right side

Fracture zygoma:

Zygoma is a very crucial component which maintains facial contour. Fractures involving zygoma is very common, in fact it is the second most common facial bone to the fractured following facial trauma (next only to nasal bones). Fractures involving maxilla not only creates cosmetic deformities, it also causes disruption of ocular and mandibular functions too. The bony architecture of this bone is rather unique, it enables it to withstand blows with significant impact without being fractured. At the most it gets disarticulated along its suture lines. Fractures can involve any of the four articulations of zygoma which include zygomatico-maxillary complex, zygomatic complex proper, orbitozygomatic complex. Fractures involving zygoma should be repaired at the earliest because it can cause both functional and cosmetic defects. Important functional defects involving this bone is restriction of mouth opening due to impingement on the coronoid process6. It is hence mandatory to diagnose and treat this condition properly. It is also important to reduce this fracture and fix it accurately, because skeletal healing after inadequate reduction can cause reduced projection of malar region of the face leading on to cosmetic deformities. Accurate assessment of position of the fractured bone should be performed in relation to skull base posteriorly and midface anteriorly. This assessment is very important before reduction is attempted to en sure accurate reduction of the fractured fragments.

Classification of zygoma fracture:

Leefort classification:

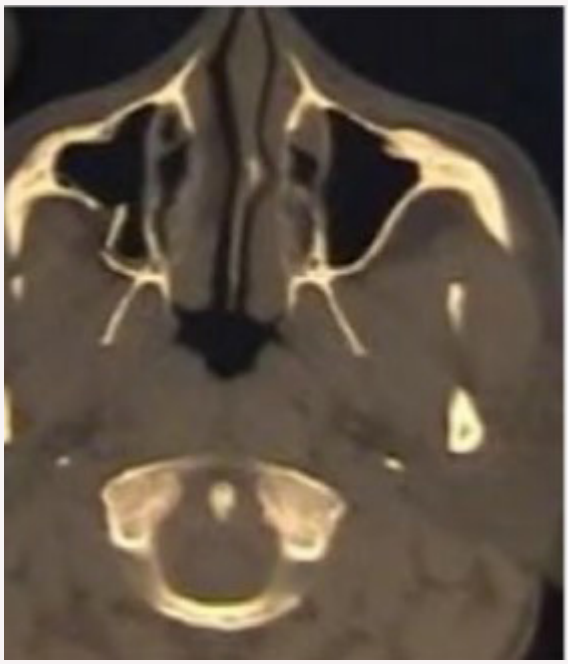
1. Non displaced – Symptomatic treatment. No reduction necessary
2. Displaced – Closed reduction is necessary
3. Comminuted – Open reduction is necessary
4. Orbital wall fracture – If ocular symptoms predominate it should be attended first. After oedema subsides then open reduction can be attempted.
5. Zygomatic arch fracture – Open reduction with stablization using microplates/ wiring.

Knight & North classification:

This classification suggested by Knight etal in 1961 helped to determine prognosis and optimal treatment modality for these individuals.

Group I fractures:

In these patients fracture lines in zygoma could be seen only in imaging. There is absolutely no displacement. These patients could ideally be managed conservatively by observation and by asking the patient to eat soft diet.

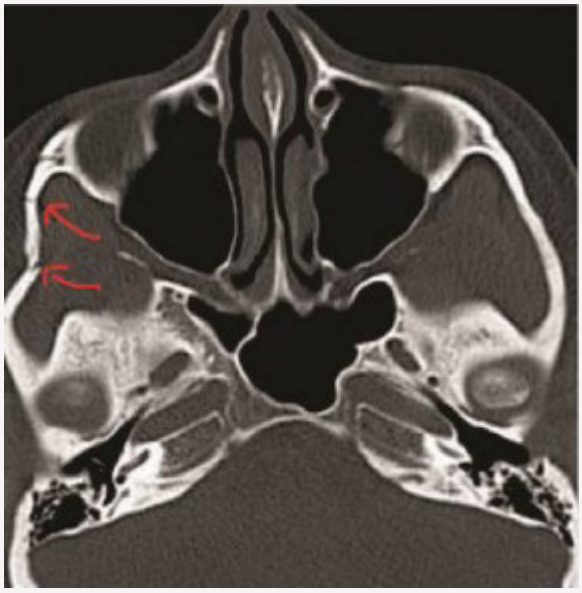


CT nose and sinuses showing fracture zygoma with medial displacement of fracture segment

Axial CT of nose and sinuses showing fracture lines involving zygoma (yellow arrows)

Group II fractures:

This group includes isolated fractures of the arch of zygoma. These patients present with trismus and cosmetic deformities.



Axial CT of nose and sinuses showing fracture of arch of zygoma (red arrows)

Group III fractures:

This include unrotated fractures involving body of zygoma.

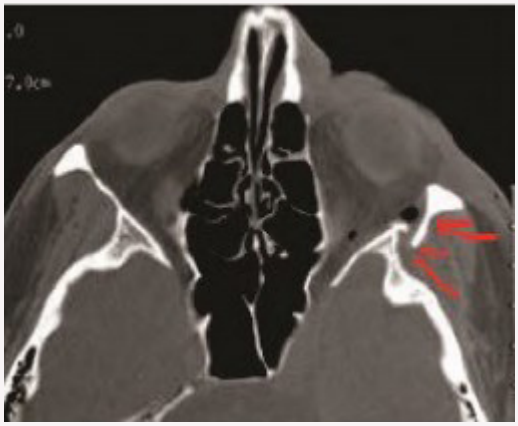
Group IV fractures:

This involves medially rotated fractures of body of zygoma.

Group V fractures:

This involves laterally rotated fractures of body of zygoma. This type of fracture is very unstable and cannot be managed by closed reduction. Open reduction will have to be resorted to.

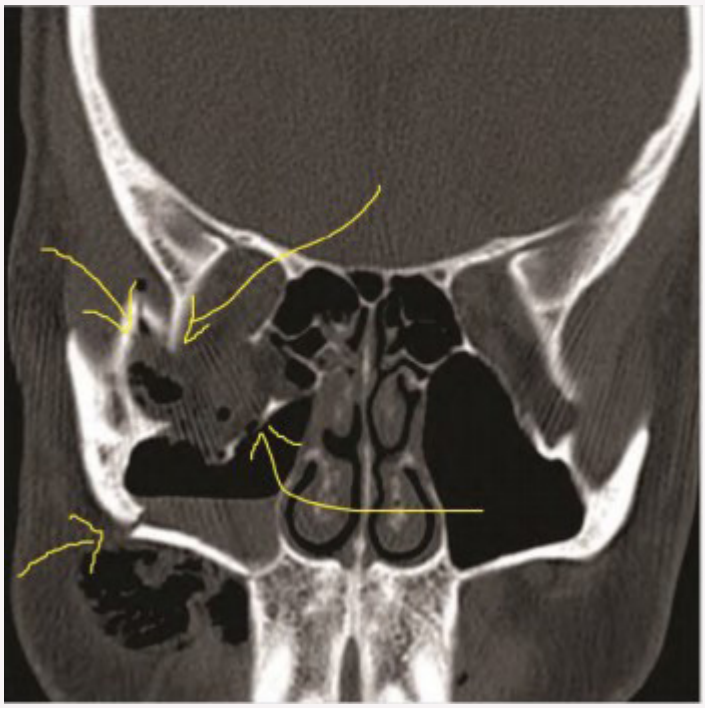
Axial CT showing medially rotated fractured body of zygoma



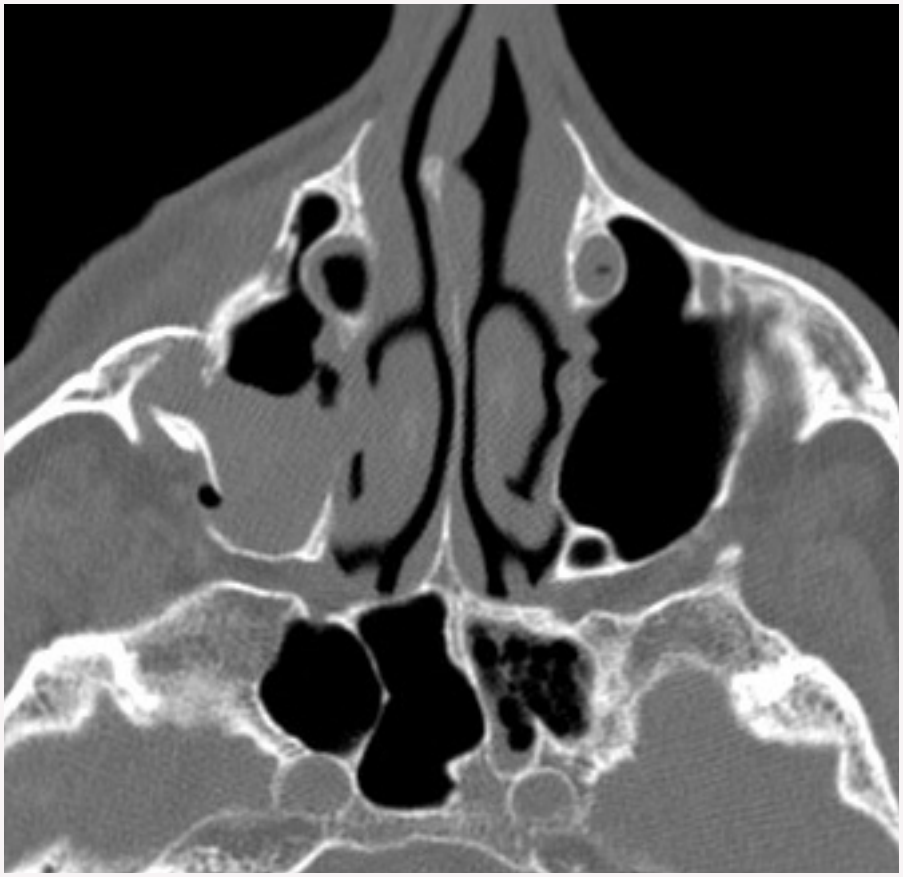
Axial CT image showing fracture body of zygoma with unstable lateral rotation

Group VI fractures:

This is complex fracture. It has multiple fracture lines over the body of zygoma. This condition is difficult to manage by closed reduction. Open reduction and microplate fixation is indicated in these patients. This type of fracture should not be managed by closed reduction alone because the presence of oedema / hematoma would mask the cosmetic deformity giving an impression that reduction has occurred. After reduction of oedema and followed by the action of masseter the fractured fragment may distract making the cosmetic deformity well noticeable.



Coronal CT of nose and sinuses showing multiple fractures involving zygoma



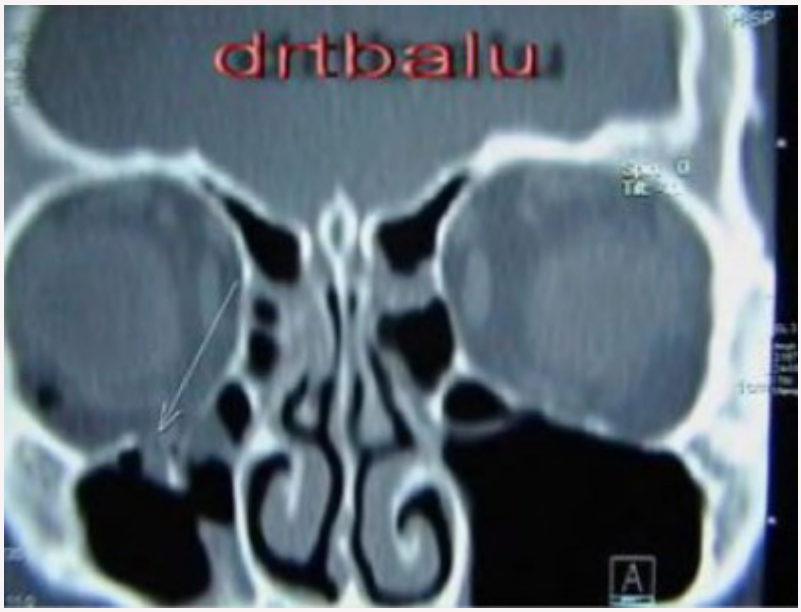
Axial CT bone window showing fracture with fragment sinking towards the anterior wall of right maxillary sinus. Note comminuted fracture of anterior wall of maxilla. Fracture posterolateral wall which causes subsidence of the floor of the orbit.

Axial CT bone window showing comminuted fracture of anterior wall of right maxilla and comminuted fracture of posterolateral wall of right maxilla. Right maxillary hemosinus is also seen.

Blow out fracture:

Blow out fracture of orbit involves fracture of orbital floor without fracture of infraorbital rim. This injury is common from frontal blow to orbit. Frontal blow to orbit causes increased intra-orbital tension causing fracture of floor of the orbit (weak point) with prolapse of orbital content into the maxillary sinus cavity. This causes enophthalmos and diplopia.

Infraorbital rim is not involved in pure blow out fracture, it is also involved then it should be considered as an impure blow out fracture8. Entrapment of inferior rectus muscle between the fracture fragments will cause diplopia in these patients



CT nose and sinuses coronal section showing blow out fracture. Note prolapse of orbital fat into the maxillary sinus (Tear drop sign)

Two theories attempt to explain this injury phenomenon:

1. Buckling theory
2. Hydraulic theory

Buckling theory:

This theory proposed that if a force strikes at any part of the orbital rim, these forces gets transferred to the paper thin weak walls of the orbit (i.e.floor and medial wall) via rippling effect causing them to distort and eventually to fracture. This mechanism was first described by Lefort.

Hydraulic theory:

This theory was proposed by Pfeiffer in 1943. This theory believes that for blow out fracture to occur the blow should be received by the eye ball and the force should be transmitted to the walls of the orbit via hydraulic effect. So according to this theory for blow out fracture to occur the eye ball should sustain direct blow pushing it into the orbit.

Water House10 in 1999 did a detailed study of these two mechanisms by applying force to the cadaveric orbit. He in fact used fresh unfixed cadavers for the investigation. He described two types of fractures:

Type I: A small fracture confined to the floor of the orbit (actually mid medial floor) with herniation of orbital contents in to the maxillary sinus. This fracture was produced when force was applied directly to the globe (Hydraulic theory).

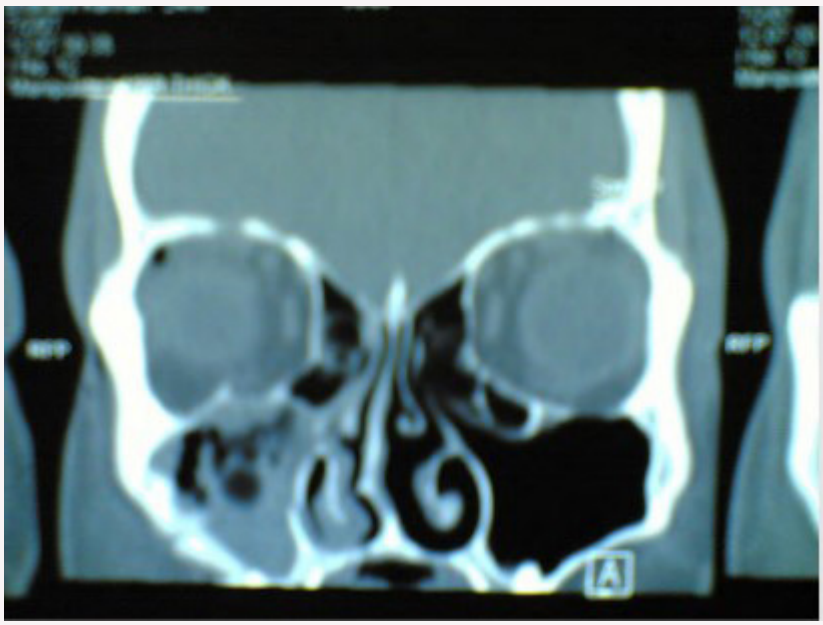
Type II: A large fracture involving the floor and medial wall with herniation of orbital contents. This type of fracture was caused by force applied to the orbital rim (Buckling theory).

Initial signs and symptoms of blow out fracture include:

1. Immediate swelling of the eye
2. Tenderness over involved orbit
3. Pain and difficulty with eye movements
4. Double vision
5. Enopthalmos
6. Numbness/tingling over lower eyelid, nose, and upper lip

Complications of blow out fracture:

1. Herniation of orbital fat into maxillary sinus
2. Orbital emphysema
3. Bleeding into maxillary sinus
4. Entrapment / rupture of ocular muscles
5. Ischemic muscle contractures
6. Cellulitis
7. Diplopia



Coronal CT shows blow out fracture right orbit with hemosinus of right maxillary antrum

Axial CT image showing fracture of antero lateral wall of right maxilla

CT of nose and sinuses showing fracture involving anterolateral wall of both maxil lary sinus. Note hemosinus of both maxillary sinuses

Fracture frontal sinus:

Fractures involving frontal bone is rather rare because of its protected location. It is basically protected from trauma by the prominence formed by the nasal pyramid. Incidence of fractures involving this area ranges between 5-15%. Fractures involving this bone is considered to be rather dangerous because of its proximity to brain as well as due to the cosmetic defects it can produce.

The proximity of this bone to the orbit and naso frontal duct doesn't help matters either. Fractures involving this area if not treated promptly can lead to:

1. Meningitis
2. Mucopyocele
3. Encephalitis
4. Cerebral abscess

It should be borne in mind that all cases of fractures involving frontal bone should be considered as a potential head injury and should be managed similarly because of its close proximity to the brain.

Causes of frontal sinus injuries:

1. Road traffic accident
2. Assault

3. Industrial accidents
4. Recreational accidents

Classification of frontal bone fractures:

Anterior table fracture
1. With / without displacement
2. With / without outflow tract injury

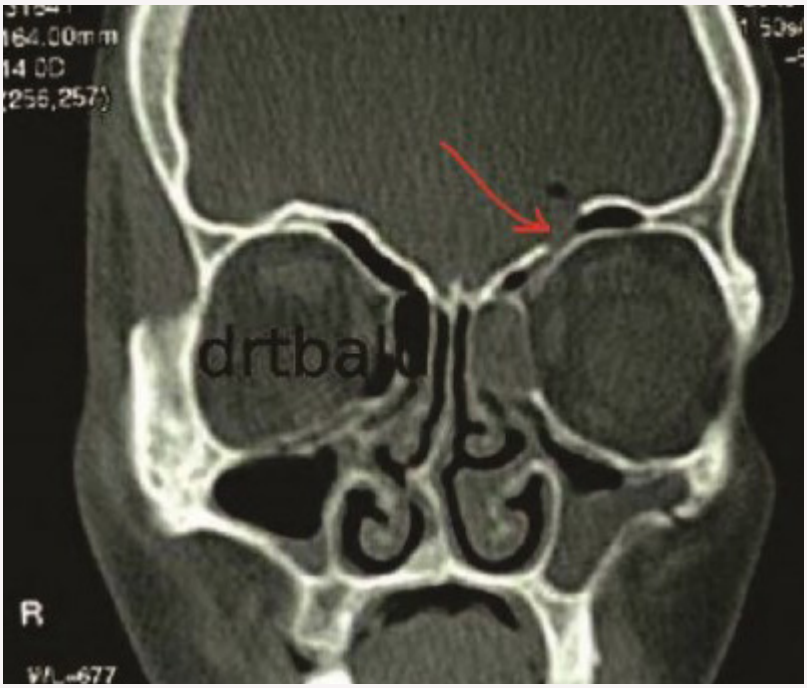
Posterior table fracture commonly occurs in combination with anterior table fracture
1. With / without displacement
2. With / without dural injury / CSF leak
3. With / without outflow tract injury

Displacement is considered to be present if it is about the width of one table of the frontal bone.

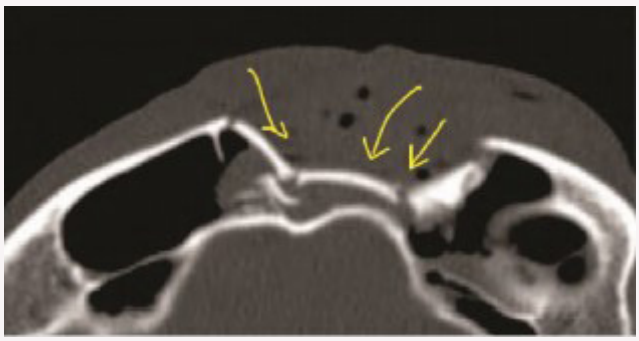
Clinical presenting features:

These include:

1. Cosmetic defect
2. Headache
3. CSF leak (in patients with posterior table fractures)

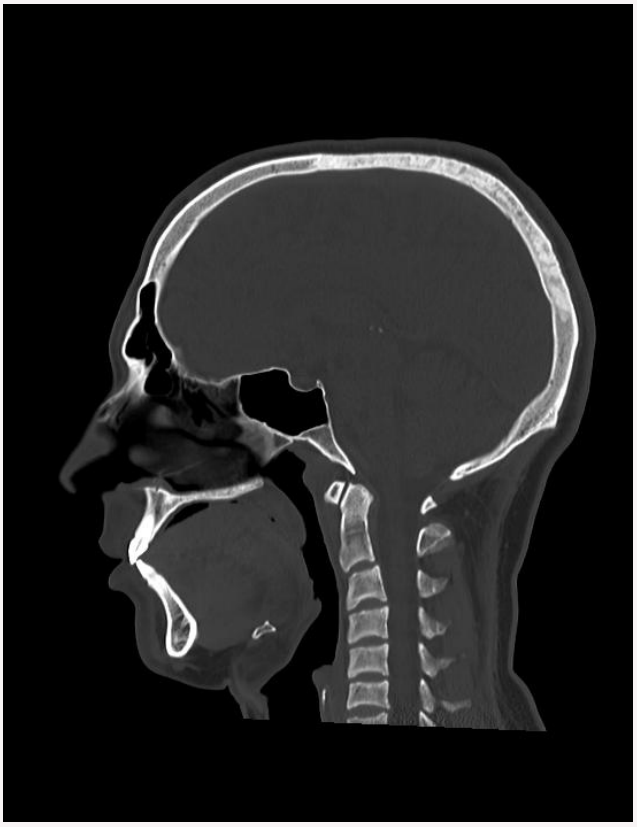


Coronal CT nose and sinuses showing fracture involving posterior table of frontal sinus (red arrow)

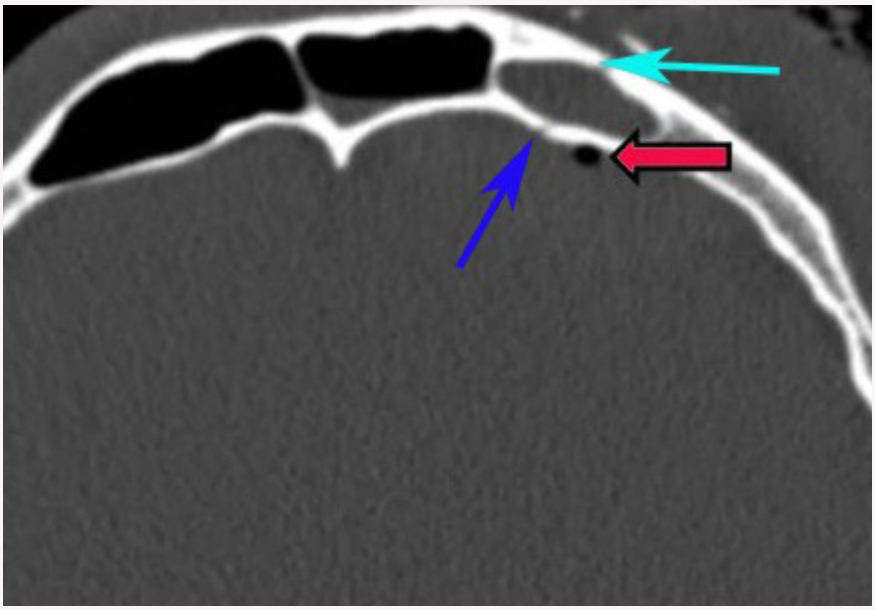


CT image showing depressed fracture of anterior table of frontal sinus

Coronal CT of nose and sinuses showing fracture involving the foveal angle (arrow)



Saggittal CT bone window showing depressed fracture of frontal bone



Axial CT showing non displaced fracture of anterior and posterior tables of frontal sinus (thin arrows) of left frontal sinus with partial opacification of frontal sinus. A small area of pneumocephalus (thick red arrow) can clearly be seen.

Congenital lesions of nose and sinuses

Congenital anomalies of the nose are considered to be relatively rare, affecting approximately 1 in every 20,0000 - 40,0000 live births. It is difficult to quantify accurately the exact incidence as minor anomalies could be overlooked or left untreated.

Embryology of nose:

Development of the nose begins during the 4th week of gestation and is largely completed by the 8th week. Development of the face is dependent on the five facial primordia and among these five primordia the frontonasal prominence is the primary structure responsible for nasal development. Migrating neural crest cells on reaching the frontonasal primordia forms the olfactory placodes which deepen into nasal pits. Mesenchymal cells that surround these nasal pits begin to proliferate, developing into the horse-shoe shaped medal and lateral nasal process on each side. The medial processes would ultimately fuse, contributing to the nasal septum and the medial crura of the lower lateral cartilages. The lateral processes develop into the nasal bones, upper lateral cartilages, ala, and lateral crura of the lower lateral cartilages. The dorsum of the nose and glabella are derived directly from the frontonasal prominence. The other four facial primordia - the paired maxillary and mandibular processes of the first branchial arch will ultimately fuse with the medial and lateral processes completing facial formation by the 14th week of gestation.

Classification systems:

Most comprehensive classification system for congenital nasal anomalies was developed by Losee in 2004. This classification was based on hypoplasia, hyperplasia, or clefting of nasal structures as well as congenital nasal masses.

Aplastic & Hypoplastic anomalies:

These include congenital anomalies of the nose in which there is a paucity or underdevelopment of nasal structures ranging from complete aplasia (arhinia) to a subtle hypoplasia of a part of the nose. This type of anomalies are thought to represent the most common class of congenital nasal anomalies.

Total arhinia is a condition in which the entire external nasal structure is absent. This includes absence of external nose, nasal cavities, and olfactory apparatus. This rare condition is caused by anomalies of chromosome 9, 13. and 21. This condition is caused by failure of nasal placode invagination. This condition is commonly associated with other midline anomalies like:

Holoprosencephaly

Bilateral choanal atresia

Hypertelorism

Meningocele

Encephalocele

Orofacial clefting

Heminasal aplasia, in which unilateral nasal agenesis is present, could occur in combination with anomalies affecting the ipsilateral face. Radiographic studies have demonstrated an associated absence of cribriform plate, which represents a loss of ipsilateral nasal placode during development.

Hypoplasia or absent portions of the nose without associated orofacial clefting are rare. Columellar agenesis (missing medial crura of the lower lateral cartilages and soft tissue covering), with normal septal development have also been reported. It has been popularly suggested that isolated hypoplastic anomalies of the nose could represent a carrier state of orofacial clefting.

Several craniofacial syndromes are known to have associated nasal hypoplasia. Binder syndrome, also known as naso-maxillary hypoplasia is characterised by hypoplasia of the anterior nasal spine and columella with midface hypoplasia. In Fraser syndrome, an underdeveloped nasal dorsum and hypoplastic nares present with cryptophthalmos. Apert and Cruzon syndromes also present with characteristic midface hypoplasia with retrusion of nasal dorsum as well as nasal cavity stenosis and maxillary sinus hypoplasia. Unilateral hypoplasia of nasal ala can be seen with hemifacial microsomia.

Bosma arhinia microphthalmia syndrome classically illustrates the common embryonic origin of nasal, ocular and pituitary structures, presenting with severe nasal hypoplasia or arhinia, microphthalmia, anosmia, and hypogonadotropic cryptorchidism.

Atresia of the anterior, middle or posterior nasal cavity can occur. Pyriform aperture stenosis is characterized by a narrowing of the premaxillary pyriform aperture resulting in an anterior nasal obstruction.

Congenital deformities of the nose such as neonatal septal deviation or nasal tip deviation have also been reported.

Hyperplastic and Duplication anomalies:

These anomalies of the nose include -

Supernumerary nostrils

Duplicate columella

True duplication of entire nose

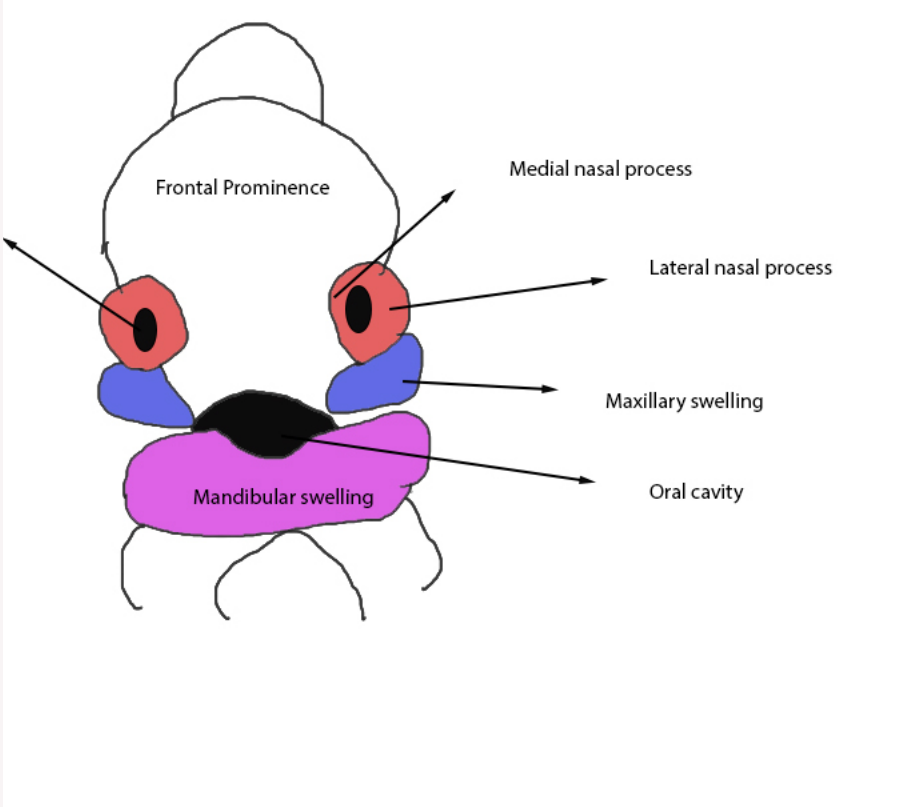
Polyrhinia.

These anomalies can be caused by an accessory olfactory pit / duplication of the olfactory placode.

In general hyperplastic and duplication anomalies are often associated with underlying bony anomalies. CT imaging is a must before deciding on the optimal management modality. Another rare congenital nasal deformity is proboscis lateralis. This condition typically presents as a tubular tract emanating from the lateral nose or medial canthus. The structure is characterized by a squamous and ciliated respiratory epithelium lining, and associated with ipsilateral sinonasal hypoplasia or aplasia. Sinonasal hypoplasia may include heminasal aplasia as well as absent turbinates, nasolacrimal duct, frontal, ethmoid and maxillary sinuses. The embryologic cause is thought to be a lesion or absence of olfactory placode early in the development. Proboscis is also associated with absence of olfactory placode. This condition can interfere with normal eye and eyelid development.

Classification system of congenital disorders of nose:

	Category	Description
Type I	Hypoplasia & atrophy	Paucity, atrophy, or underdevelopment of skin, subcutaneous tissue, muscle, cartilage, and/or bone
Type II	Hyperplasia and duplications	Excess tissue, ranging from duplication of parts or complete multiples
Type III	Clefts	The Tessier classification of craniofacial clefts is applied
Type IV	Neoplasms & vascular anomalies	Benign and malignant neoplasms, vascular anomalies



Development of nose 4 weeks embryo

Nasal clefts:

Clefting of the nose is caused by the failure of the frontal process to develop appropriately and may present as either medial or lateral clefts. Nasal clefts could range from a well defined cleft of the nasal floor associated with cleft lip and palate abnormalities to lateral involvement of the frontal bone or orbit. The most commonly used classification system is that the one developed by Tessier in 1970. This classification uses the orbit as the primary structure of reference and localizes clefts of the soft tissue and bone of the face and cranial vault.

The craniofacial clefts that applies to the nose are the Tessier No. 1, 2, and 3 clefts and their cranial extensions: Tessier No 11, 12, 13 and 14.

Median facial clefting, also known as frontonasal dysplasia represents the Tessier No 0/14 cleft. The most severe presentation of this cleft is a frontonasal encephalocele with hypertelorism and a broad nasal dorsum with the appearance of failure of closure of the anterior neuropore. The forehead is typically "V" shaped.

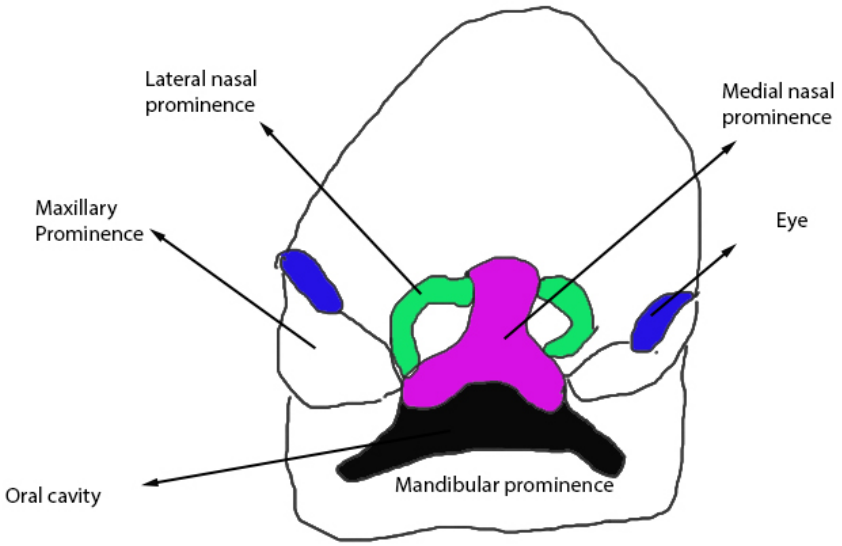
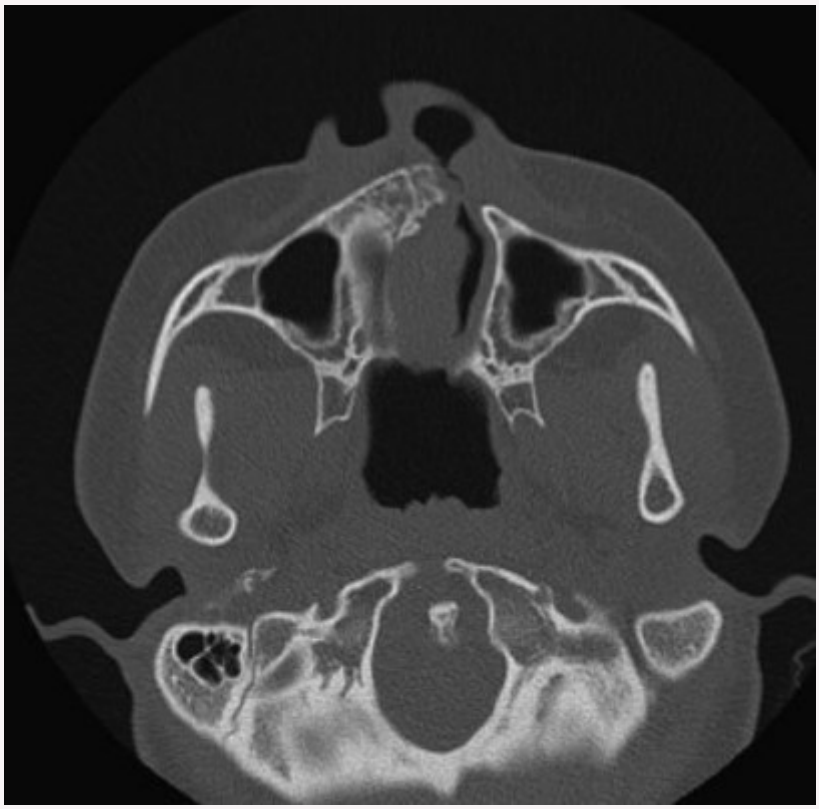


Image showing development of nose 8weeks embryo

Frontorhiny is considered to be an intermediate presentation, characterized by hypertelorism, a wide nasal dorsum, bifid nasal tip and a broad columella with widely separated narrow nares. At the other extreme end of the spectrum is mild nasal bifidity representing the microform condition of this cleft.

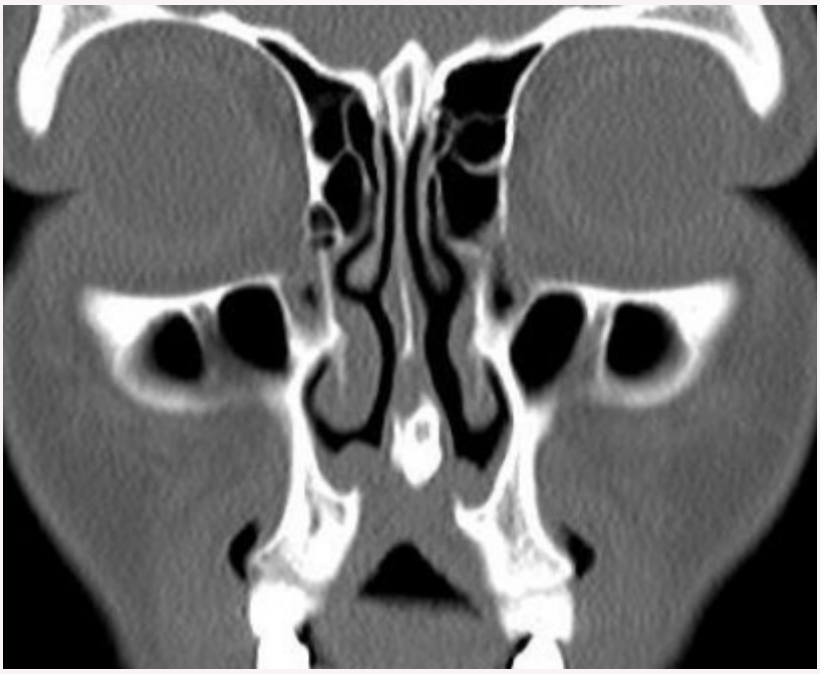
Coronal CT showing arhinia involving the left side. Note the non development of nasal airway, ehtmoid air cell system and maxillary sinus on the left side. Note the fusion of the irregular left frontonasal process fusing with the nasal process of frontal bone apically near the glabella.



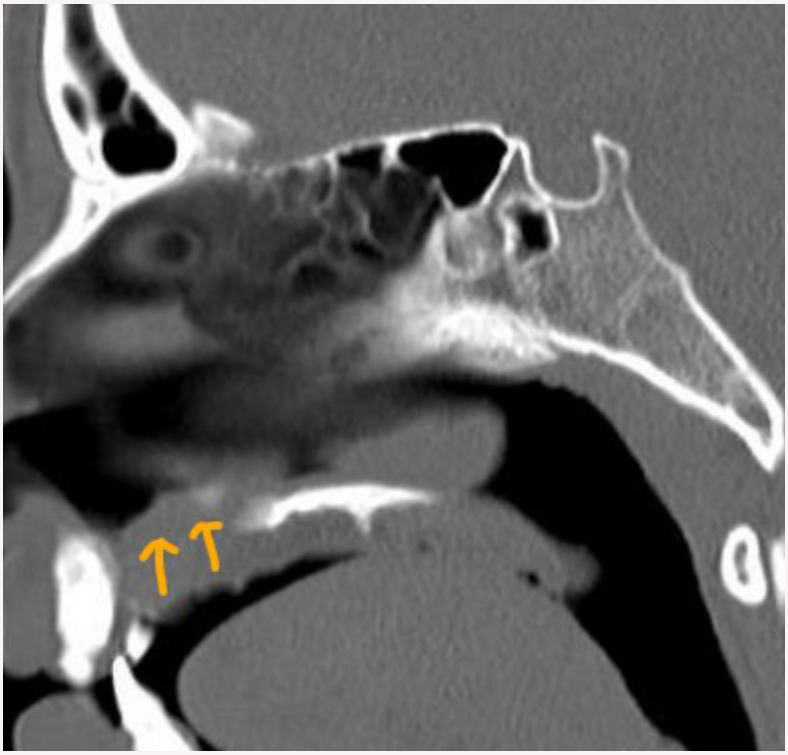
Axial CT showing left sided alveolar cleft. This condition usually accompanies cleft lip / cleft palate

Alveolar cleft occurs in response to divergence from normal development during frontonasal prominence growth, contact, and fusion. The most common alveolar portion of the cleft is located between the lateral incisor and canine.

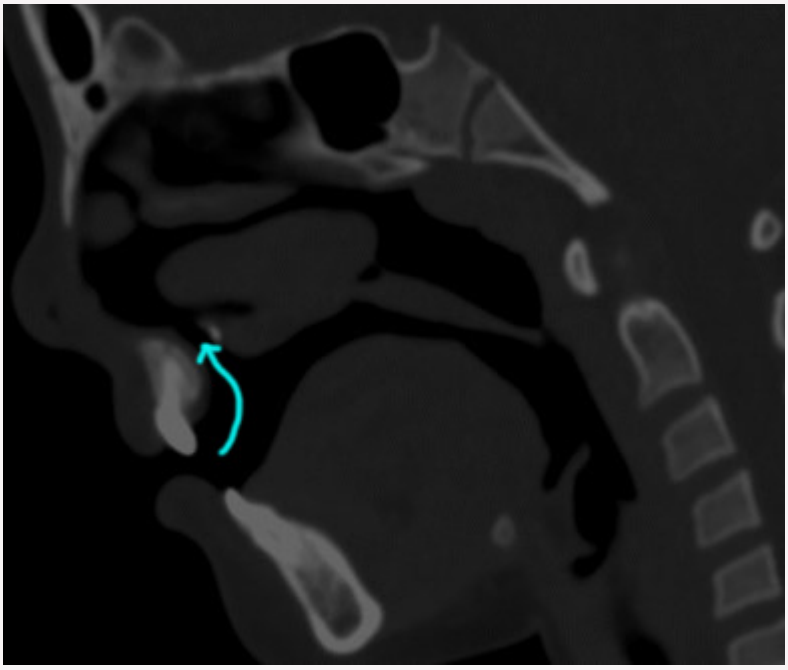
Coronal CT bone window showing isolated cleft palate and cleft alveolus (blue arrow)



Coronal CT bone window showing cleft alveolar process and cleft palate



Sagittal CT bone window showing cleft palate (Yellow arrow)



Sagittal CT bone window showing cleft palate (green arrow) with persistent oronasal fistula

Congenital nasal masses:

These are rare lesions that can present in the external nose as well as within the nasal cavity, paranasal sinuses, nasopharynx, oral cavity and orbit. These masses should be differentiated from encephalocele, meningocele, glioma, dermid cyst, vascular malformations, and benign and malignant neoplasms.

Nasal dermoid cysts and sinuses:

Nasal dermoid lesions could present as cystic masses, sinus tracts, or a combination of these. The most common location of these lesions is the lower third of nasal dorsum. These lesions could also occur from the glabella to the tip of the nose or columella.

Clinically, these cystic lesions could present as firm, slow growing mass that:

Are compressible

Do not transilluminate

Often has an associated dermal pit.

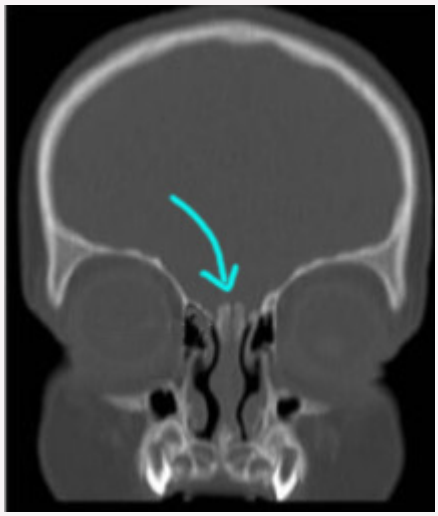
These masses do not enlarge with crying or straining. Intracranial extension of these masses could be to the extent of 40%. Imaging characteristic suggestive of intracranial extension include:

1. Bifid crista galli

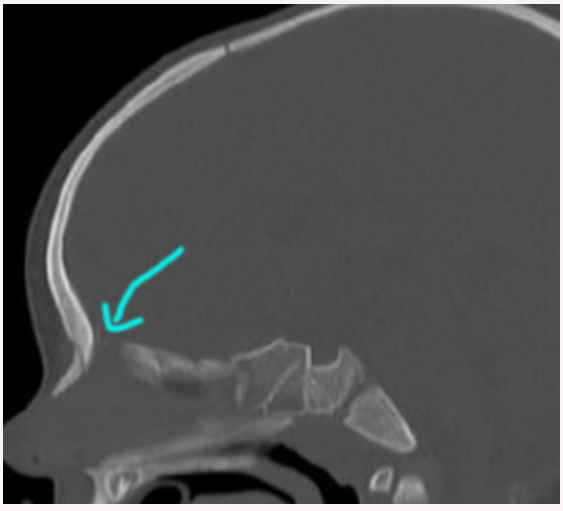
2. Enlargement of foramen caecum

Given the fact that ethmoid bone has incomplete ossification CT imaging alone could produce false positives. If these findings are evident on a CT image then MRI should definitely be performed.

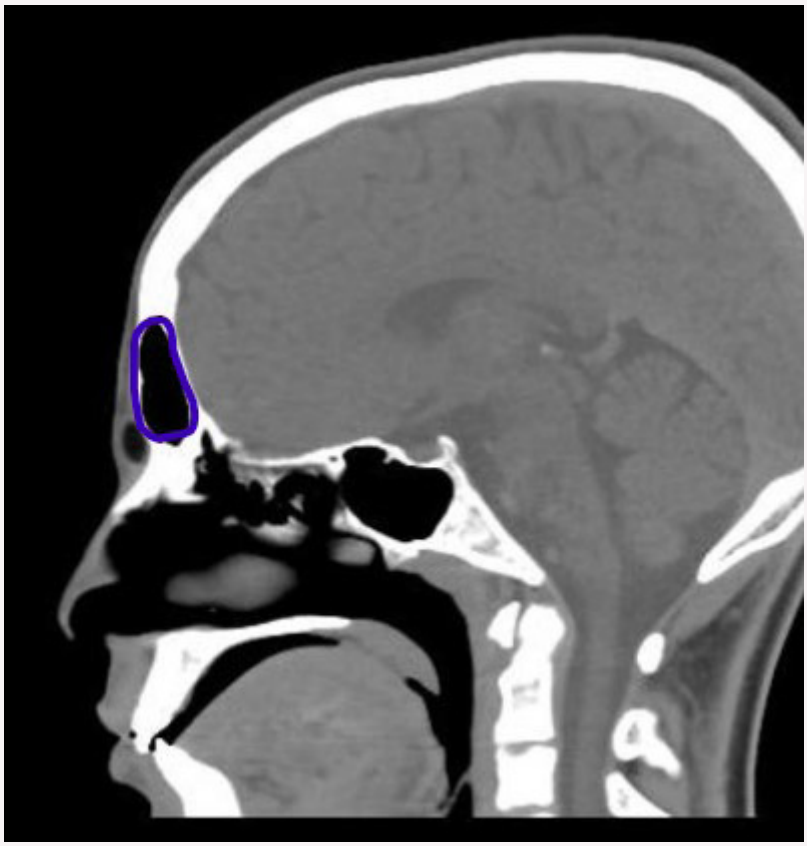
If dermoid cysts and sinuses are left untreated, then local inflammation could develop leading on to abscess formation. If intracranial extension is present then it could ultimately lead to CSF leak, meningitis, and cavernous sinus thrombophlebitis.



Coronal CT of nose and sinuses showing bifid crista galli



Saggital CT image showing enlarged foramen caecum (blue arrow)



Sagittal bone window CT showing a small well defined lesion of low (fat) density of mean attenuation at the midline of the nasofrontal region (purple ring). There is no evidence of underlying bony defect / bone remodeling.

Axial CT showing a small well defined lesion of low (fat) density at the midline of nasofrontal region (green circle). No evidence of underlying bone defect.

Nasal encephaloceles:

Congenital nasal encephaloceles are extracranial herniation of meninges and brain tissue. Encephaloceles are classified by the site of herniation. Sincipital encephaloceles usually present at the forehead, nasal dorsum or orbit.

Sincipital encephalocele include:

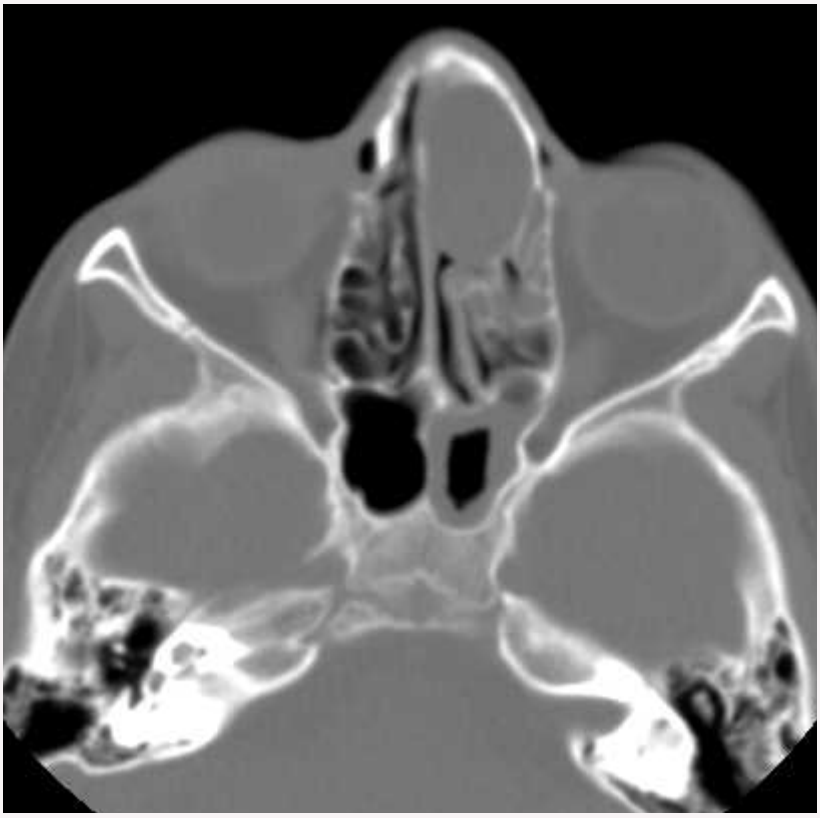
Nasofrontal

Nasoethmoid

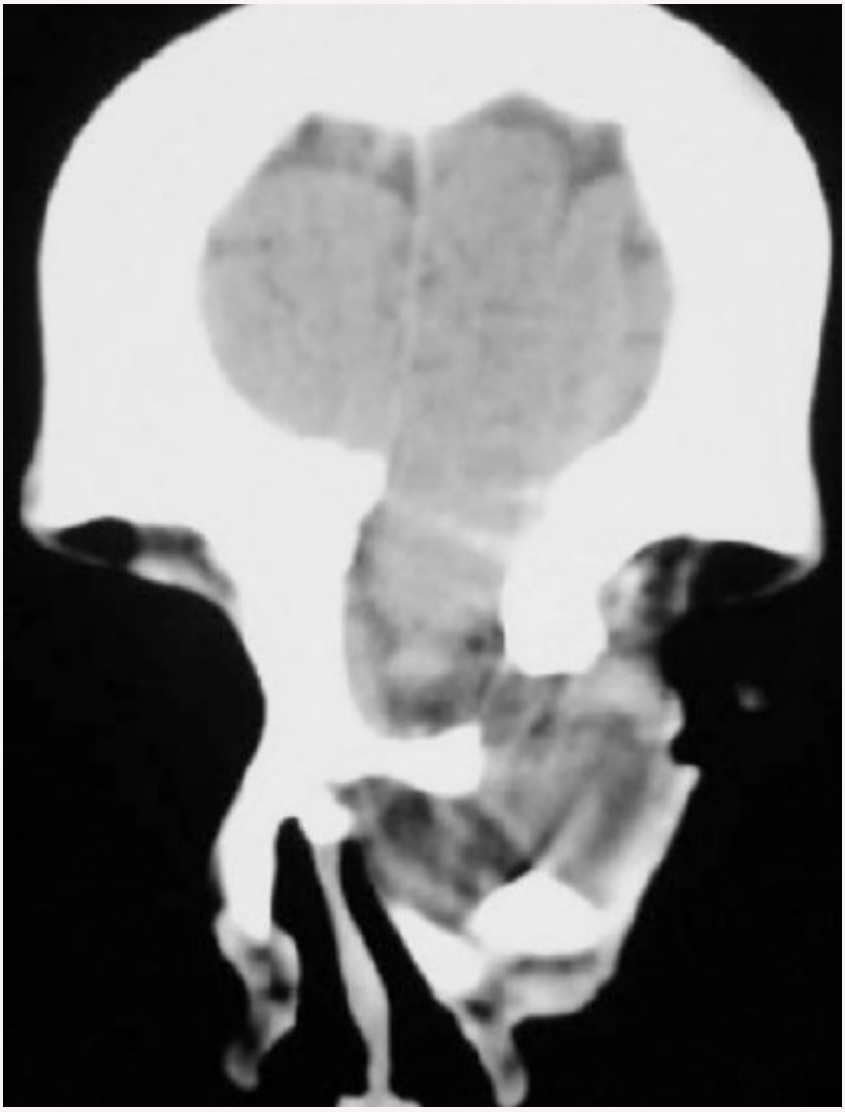
Naso-orbital

The external mass will present at one of the above mentioned sites. The internal defect is invariably located in the midline.

Encephaloceles are soft compressible masses that transilluminate. When present intranasally they could be mistaken for polypi. Patients with encephaloceles demonstrate a positive Furstenberg test (the mass enlarges with increased intracranial pressure caused by crying / straining). On MRI scans encephaloceles will demonstrate CSF that is in continuity with the intracranial space. These lesions carry the risk of CSF leak, meningitis and intracranial absess if left untreated.

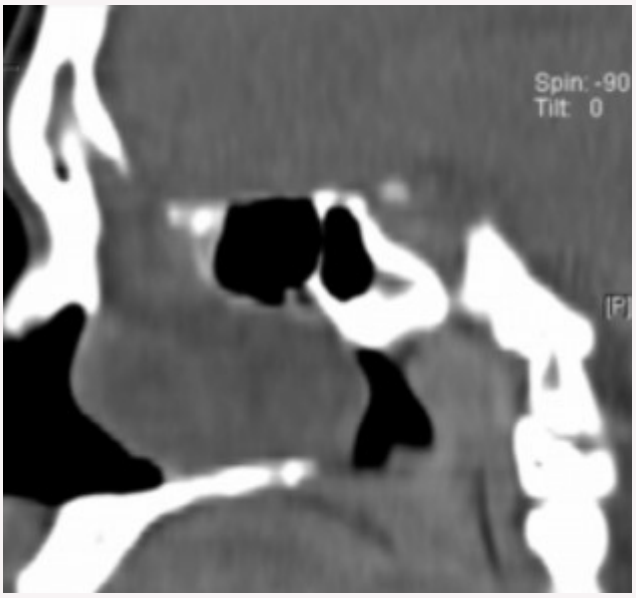


Axial CT showing bony defect in left cribriform plate associated with a large, solid mass lesion emerging through it to fill and expand the entire left nasal fossa. Note the associated mucosal thickening of anterior ethmoidal cells, left sphenoid sinus and left maxillary antrum. Nasal septal displacement is also seen.



Coronal CT showing defect in the cranial base. Herniation of brain tissue into the nasal cavity could be seen.

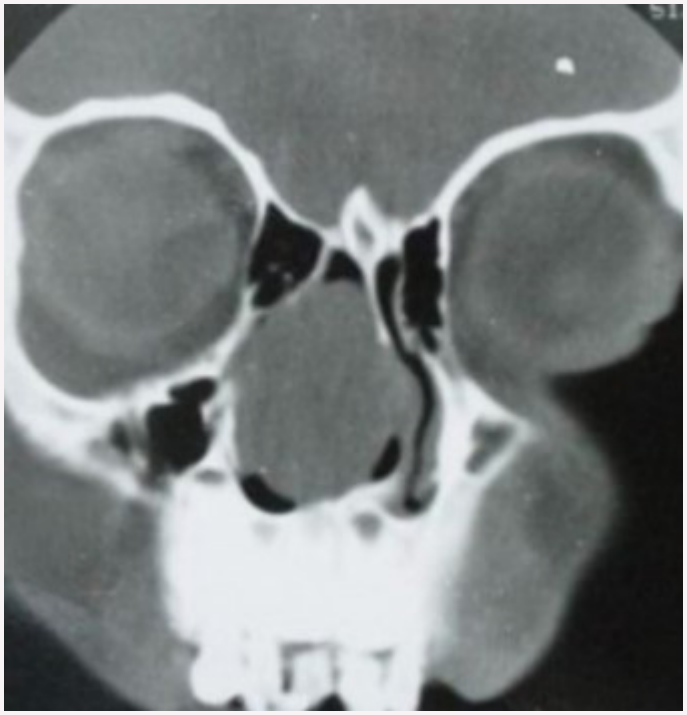
Coronal CT nose and sinuses showing defect in the anterior cranial fossa through which herniation of intracranial contents could be seen



Sagittal CT of nose and sinuses showing anterior cranial fossa defect with prolapse of intracranial contents

Nasal gliomas:

These tumors represent brain tissue that has persisted through an anterior cranial defect. Unlike encephaloceles, the meningeal connnection is not there. The term glioma is a misnomer. Hence the terms encephaloma, nasal cerebral heterotopic has been proposed. These mass lesions are typically firm, noncompressible and can present from the glabella to the nasal tip. Roughly 60% of these tumors are extranasal, 30% intranasal and 10% a combination of these two. Intranasal gliomas can easily be mistaken for nasal polyposis, they are less translucent. A pedicle of glial tissue with dural connection is found in 20% of these patients. Gliomas could become infeccted and can result in deformation of the septum or nasal bones.

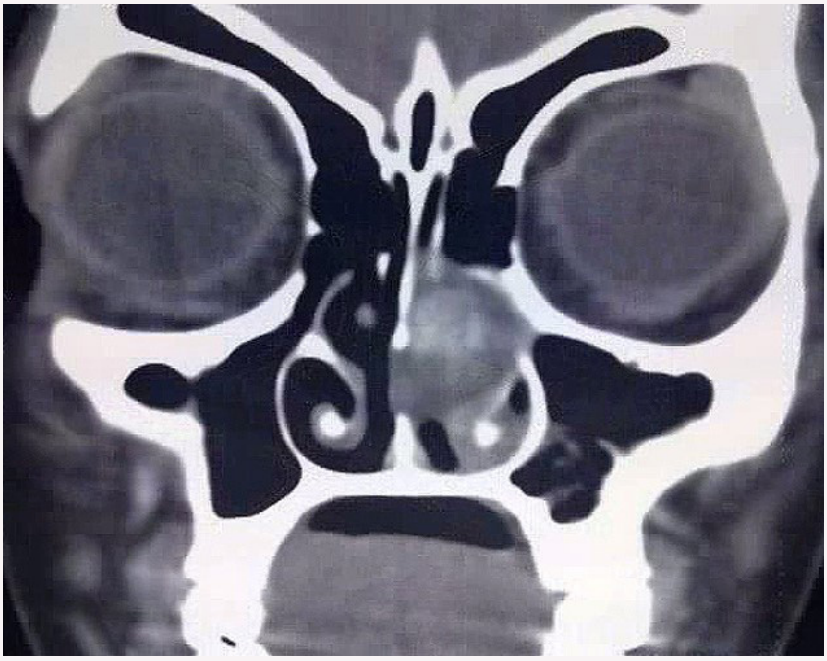


Coronal CT revealing a well defined soft tissue mass occupying the right nasal cavity displacing the nasal septum to the left side. The Mass could be seen compressing the lateral wall of right nasal cavity.

Nasal gliomas are considered as heterotopic brain tissue found outside the cranium but are not covered with meninges. Unlike encephaloceles it does not communicate with the intracranial cavity.

Vascular anomalies of the nose:

The most common vascular anomaly of the nose is nasal hemangioma. Infantile hemangioma is designated as a benign vascular tumor of endothelial cell origin which could appear during the first weeks of life. Natural history is characterized by rapid proliferation phase during the first year of life followed by a quiescent and then involutional period that can last for several years.

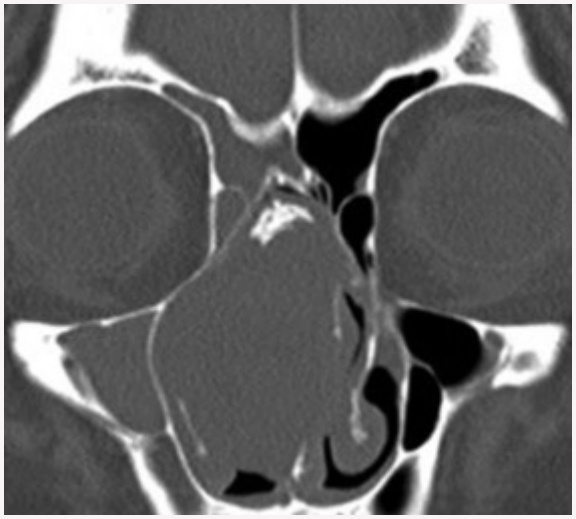


Coronal CT scan contrast showing enhancing soft tissue lesion within the left nasal cavity. Probable dignosis (Hemangioma nose)

Solitary fibrous tumor of nasal cavity:

Solitary fibrous tumors of nose and sinuses are very rare. These lesions are also known as benign fibrous mesothelioma. These tumors were initially considered to arise from mesothelium and hence could also be termed as mesothelioma.

These lesions appear as mucosa covered mass filling the entire nasal cavity.



Coronal CT of nose and sinuses Bone window showing expansile soft tissue mass occupying right nasal cavity. Note the medial wall of right maxilla is pushed laterally. Nasal septum is pushed to the left side by the expanding mass. Areas of focal calcification could also be present in these patients

Lipoma Nose:

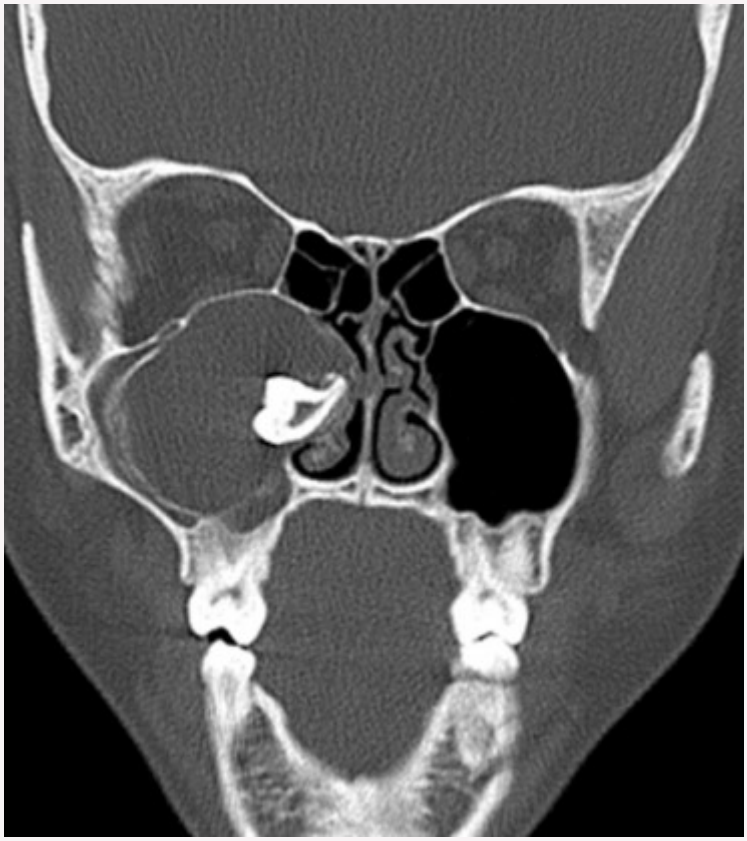
Lipomas are the most common benign soft tissue tumors of adults. These tumors are composed of mature fat cells with no cellular atypia. Osteolipomas are actually a histologic variant of lipomas that have undergone osseous metaplasia. Osteolipomas contains a variable mixture of adipose tissue, lamellar bone, woven bone and osteoblasts.

CT scan nose and sinuses showing heterodense soft tissue mass arising from skull base onn the left side. Note the presence of patchy calcification in the mass lesion.

Cystic Lesions

Cystic lesions of maxilla could be unilocular / multilocular. They usually have well defined sclerotic borders. Cysts can be circular / oval / fluid filled. Some of these cysts could be expansile. Some of these cysts especially odontogenic keratocytes and simple bone cysts could show scalloped borders.

Cysts that origintaes in bone usually have a well defined corticated border that is characterized by a thin radiopaque line which is known as inert margins. If there has been secondary infection then this border could become thicker, sclerotic and ill defined. Most of these cysts have a radiolucent center.



Coronal CT showing a cystic lesion in the right maxillary antrum. Unerupted tooth can be seen within the cyst. Diagnosis - Dentigerous cyst. Note the thin rim of bone along the inner margin of the true maxillary antral wall. This indicates that the lesion has its origin outside the antrum.

Dentigerous cyst:

This is a type of odontogenic cyst that forms between the enamel epithelium and enamel of the crown of the affected tooth, with fluid accumulation. These cysts always includes the crown of an unerupted tooth / impacted tooth. This cyst is commonly observed in the third molar region of the mandible. These cysts are also seen in the maxilla.

Two types of dentigerous cysts have been reported:

Developmental:

These cysts are the most common type. This cyst surrounds the crown of an unerupted tooth by fluid accumulation between the layers of the enamel organ.

Inflammatory:

This is rather rare occurring as a result of periapical inflammation from a nonvital primary tooth. The spread of periapical inflammation could affect the germ of the permanent tooth and could induce the formation of the cyst. Inflammatory type of dentigerous cyst is usually associated with the roots of a nonvital primary tooth. The presence of overlying nonvital nectotic primary first molar increases the possibility of it being inflammatory in nature.

Axial CT showing well defined lobulated cystic lesion arising from the posterior portion of left maxillary alveolus extending to the maxillary sinus. The walls are thin and smooth with no evidence of periosteal reaction. Superiorly the lesion could be seen around the crown of the impacted and displaced 28th teeth.

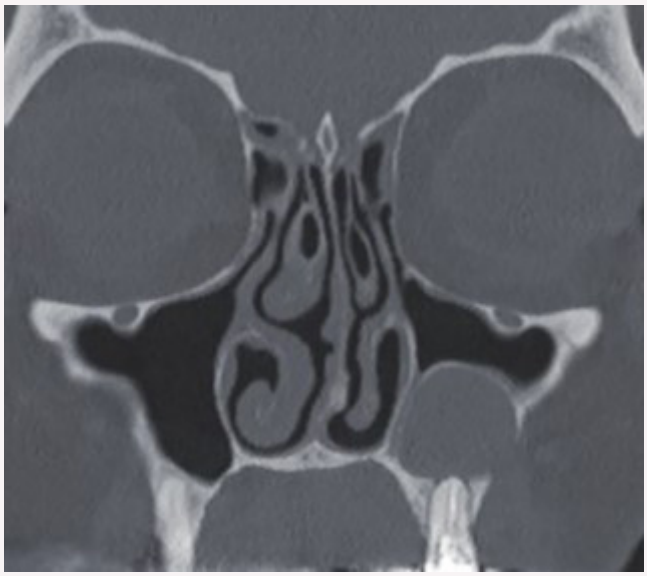
Coronal CT bone window showing a cystic lesion involving left maxillary sinus. Unerupted tooth could be seen within the cyst cavity.

Coronal CT bone window showing dentigerous cyst arising from the margin of unerupted tooth in the left maxillary sinus

Glandular odontogenic cyst:

This is an uncommon jaw bone cyst of odontogenic origin. It was first descrined in 1987 by Gardner et al and hence it is also known as the Gardner's cyst. The term glandular odontogenic cyst was coined by Gardner as the cyst contained mucin elements.

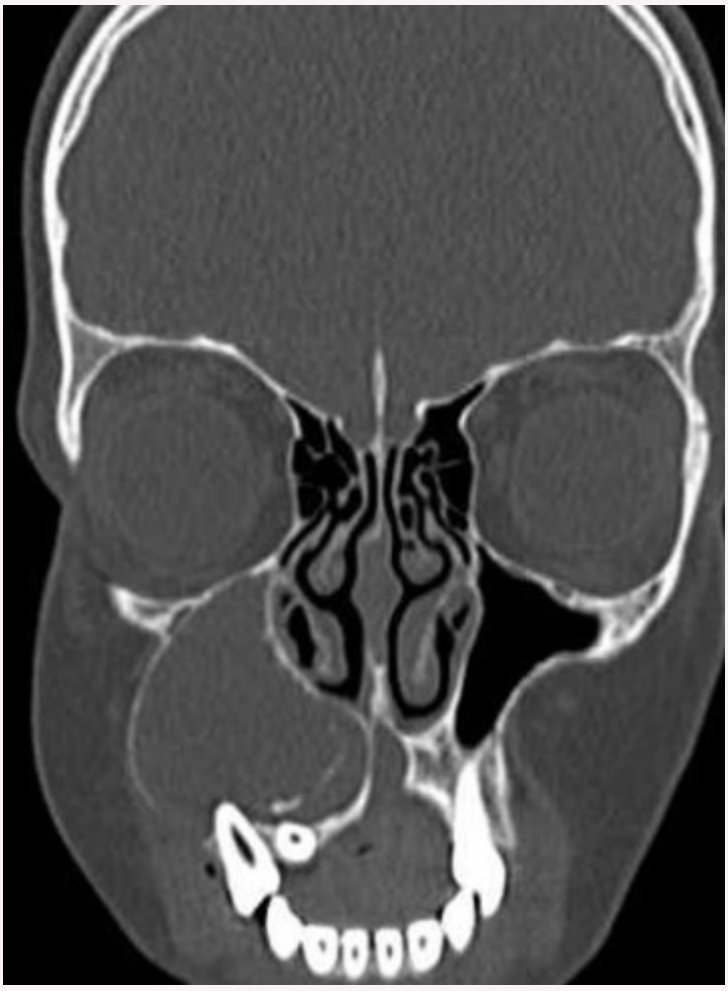
This lesion occurs in middle aged patients with slight male predilection. Common in mandibular region in comparison to maxilla. Histologically these cysts shows non keratinized stratified squamous epithelial lining, focal plaque like thickenings within the lining, microcysts containing mucin, mucous cells and hyaline bodies.



Coronal CT showing cystic lesion within left maxillary sinus abutting the dental root. This condition was diagnosed as Glandular odontogenic cyst.

Odontogenic keratocyst:

These cysts contain keratinized epithelium and is thought to arise from the dental lamina and other sources of odontogenic epithelium. Mandible is affected twice as the maxilla. It is commonly seen in the posterior body / ramus. The cyst margins are usually well corticated and could have a scalloped contour. Multiple odontogenic keratocysts can be seen in association with basal cell nevus (in patient with Gorlin-Goltz syndrome). Majority of these lesions are solitary.



Coronal CT showing a solitary unilocular lesion with smooth, corticated borders in right maxilla extending into the right maxillary sinus. Density of cystic contents could vary with the viscosity of the cyst contents. If cortical breach is seen then it is suggestive of possible soft tissue involement as well. Diganosis - Odontogenic keratinocyst.

This condition needs to be differentiated from

Dentigerous cyst.

The major imaging differences being:

Both dentigerous cyst and odontogenic keratinocyst can be positioned pericoronally. Dentigerous cysts tend to attach at the cemento-enamel junction of teeth.

Radicular cyst:

These cysts does not scallop, does not exhibit septation, and is often expansile. These cysts are centered at the apices of non-vital teeth.

Ameloblastoma:

These cysts tend to be multilocular, more expansile with soap bubble or honeycomb appearance. Ameloblastoma is considered to be more aggressive and could cause more significant tooth resorption. A long standing odontogenic keratinocyst could mimic an ameloblastoma.

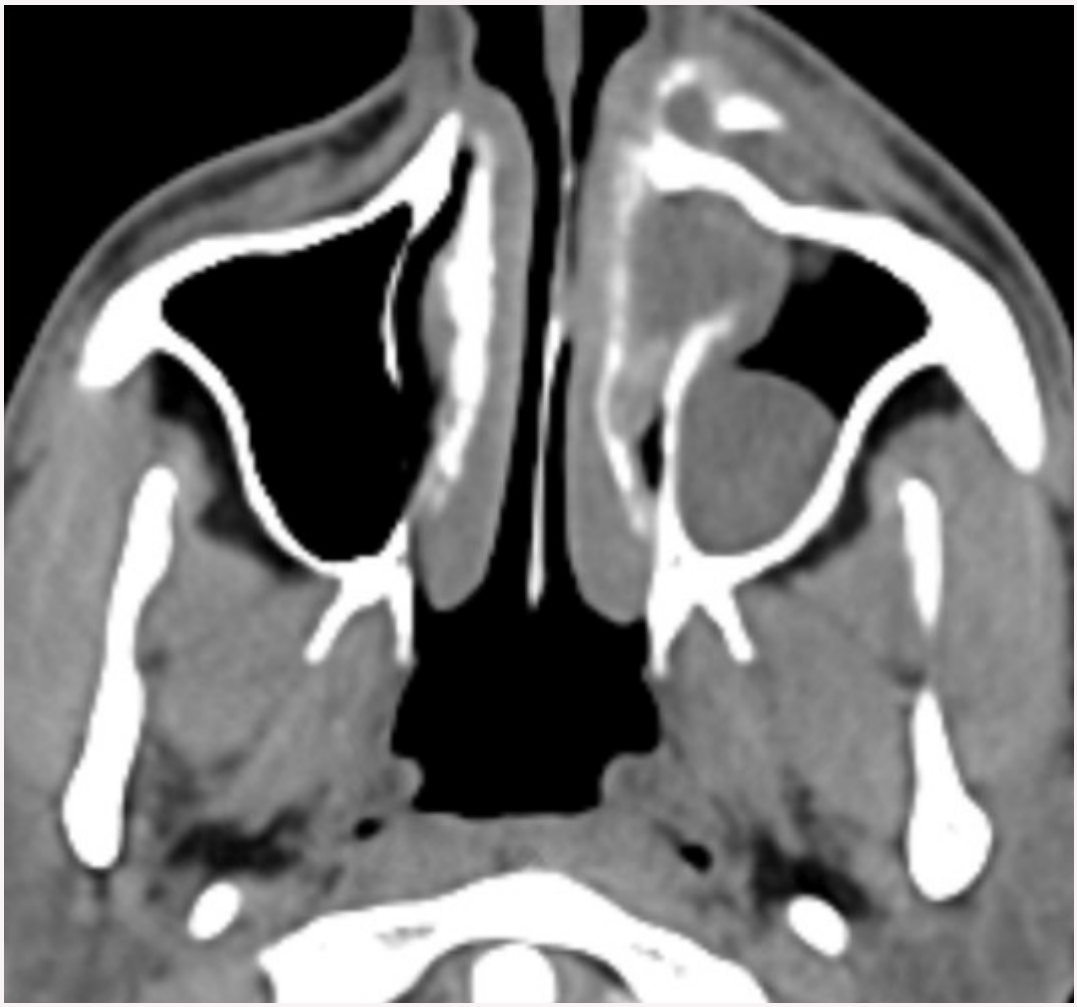
Simple bone cyst:

Could be challenging to differentiate between odontogenic keratinocyte because simple bone cysts could also exhibit minimal expansion and also has a tendency to spare the lamina dura as well as the periodontal ligament spaces. Odontogenic keratinocyte has a tendency to efface lamina dura.

Radicular cyst:

These cysts are also known as periodontal, periapical, or dental cysts. These cysts arisee from the periodontal ligament secondary to low grade irritation and infection involving commonly the apices of non-vital teeth. Radicular cysts are associated with caries teeth with pulp necrosis. A resiual cyst is a persistent Radicular cyst after extraction of the involved tooth. Nearly 60% of these cysts occur in the maxilla, and the incisors and canines are commonly involved. These cysts have a tendency to grow rather slowly and does not reach large sizes.

Radiologically these lesions appear in CT as radiolucent, unilocular and have corticated margins. Margins could be altered when the cyst become secondarily infected. These cysts could invaginate into the maxillary sinus.



Axial CT showing a large lobulated expansile unilocular cystic lesion involving the left maxilla. The cyst could be seen to expand into the ipsilateral maxillary sinus with scalloped well corticated borders with homogenous density of the cyst content. Probable diagnosis could be odontogenic keratinocyst.

Axial CT showing showing lobulated expansile unilocular cystic lesion in left maxilla expanding it. Note the scalloped well corticated borders and homogenous density of the cyst content. These features are characteristic of odontogenic keratocyst.

Coronal CT showing a lobulated expansile cystic lesion involving the left maxilla. Note the scalloped and well corticated bony margin around the cystic lesion. Contents of the cyst appear homogenous. These features are suggestive of odontogenic keratocyst.

Coronal CT showing an expansile radicular cyst occupying the entire right maxillary sinus eroding the cortex of its inferior wall. These features are suggestive of radicular cyst.

Axial CT showing expansive cystic process involving the root of the second right maxillary molar tooth.

1

Nasopalatine duct cyst:

This was first described by Meyer in 1914. This cyst is also termed as incisive canal cyst, and has been postulated to arise from embryonic remnants of nasopalatine duct which is the communication between the nasal cavity and anterior maxilla. This is seen in the developing fetus. Most of these cysts develop in the midline of anterior maxilla near the incisive formane. This cyst is the most common non-odontogenic cysts of oral cavity.

Axial CT showing solitary well defined oval / round unilocular radiolucency between the central incisors. They could appear "heart shaped" if the anterior nasal spine is superimposed. Root resorption and tooth displacement could also be present.

Calcifying odontogenic Cyst:

These are also known as keratinizing and calcifying ameloblastoma, Keratinizing and calcifying odontogenic cyst or Gorlin cysts. In younger patients these cysts are usually central; in older patients they are usually peripheral. They usually present as painless swellings. These lesions are often associated with an unerupted tooth and could resorb adjacent tooth roots.

These lesions usually appear are radiolucent or characteristically could contain radiopaque pebble like flecks of calcifications.

Coronal CT nose and sinuses showing well defined unilocular lesion inside right maxillary sinus confined within the boundaries of the maxillary sinus. Note ring calcification inside the mass. These features are suggestive of calcifying odontogenic cyst.

Buccal bifurcation cyst:

These cysts are also known as paraental or mandibular infected buccal cysts. This condition affect children from 6-11 years of age. These cysts are found on the buccal aspect of viable mandibular molars and can be associated with local pain and swelling. These cysts can resorb or displace teeth.

Etiology of this condition is not clear. It has been postulated that the cystic epithelium could arise from reduced enamel epithelium, cell rests of Malassez, remnants of the dental lamina or crevicular epithelium. This lesion presents as a U-shaped radiolucent lesion that overlaps the dental roots.

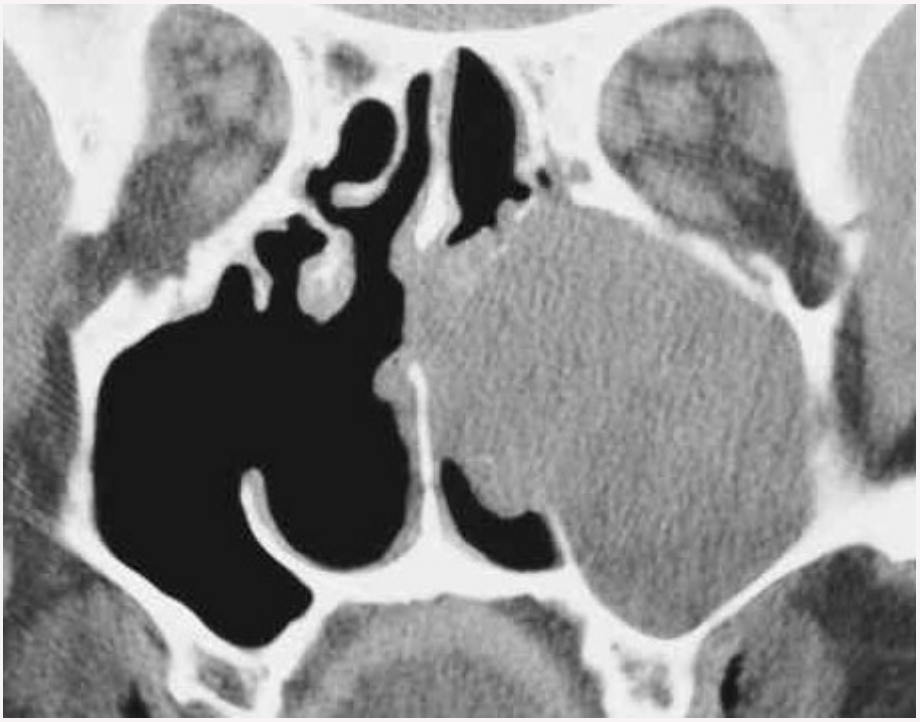
Ameloblastoma:

These are locally aggressive benign tumor that commonly arises from mandbile and rarely form the maxilla. This condition usually present as a slowly but continuously growing hard painless lesion near the angle of the mandible. The most common form of ameloblastoma (the multicystic form) was formerly known as adamantinoma of the jaw.

In CT images these lesions are seen as well demarcated unilocular lesions with soap bubble appearance.

Unicystic ameloblastomas are well demarcated unilocular lesions that are often seen in pericoronal position. Sometimes these lesions could be indistinguishable from other unilocular pericoronal lesions like dentigerous cysts.

Coronal CT showing ameloblastoma of left maxilla. Honey comb appearance of the tumor should be noted.

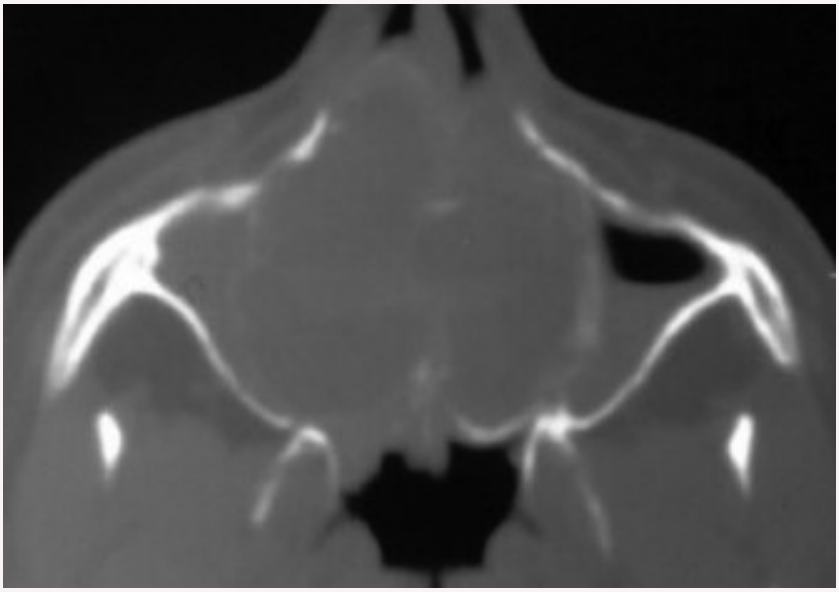


CT iamge showing ameloblastoma confined to the maxillary sinus with destruction of its medial wall. The same mass could be seen extending into the nasal cavity.

Aneurysmal bone cyst:

This cyst commonly involves the mandible in the faciomaxillary region. Maxilla is a rare site. It is neither an aneurysm nor a cyst. WHO defines this lesion as an expanding osteolytic lesion consisting of blood filled spaces of variable size separated by connective tissue septa containing trabeculae of osteoid tissue and osteoclast cells. These tumors are usually found within bones with high venous pressure and marrow content.

Radiographically these lesions appear as blow out or ballooned.



Axial CT of nasopharynx region showing expansile lesion with thinning of the bony cortex. Both the pterygoid plates are intact.

Atrophic Rhinitis

Introduction:

Atrophic rhinitis is defined as a chronic nasal disease characterized by progressive atrophy of the nasal mucosa along with the underlying bones of turbinates. There is also associated presence of viscid secretion which rapidly dries up forming foul smelling crusts. This fetid odor1 is also known as ozaena. The nasal cavity is also abnormally patent. The patient is fortunately unaware of the stench emitting from the nose as this disorder is associated with merciful anosmia. This disease is rather rare in developed countries, but are rather common in developing countries. Now a days it is more common as a sequelae of medical interventions. Overzealous turbinate surgery has been implicated as a probable iatrogenic cause.

Synonyms:

The following are the various terminologies used to indicate the same condition:

1. Rhinitis sicca
2. Dry rhinitis
3. Ozena
4. Open nose syndrome
5. Empty nose syndrome

Etiology:

The etiology of this problem still remains obscure. Numerous pathogens have been associated with
this condition, the most important of them are:

1. Coccobacillus
2. Bacillus mucosus
3. Coccobacillus foetidus ozaenae
4. Diptheroid bacilli
5. Klebsiella ozaenae.

These organisms despite being isolated from the nose of diseased patients have not categorically been proved as the cause for the same.

Other predisposing factors include:

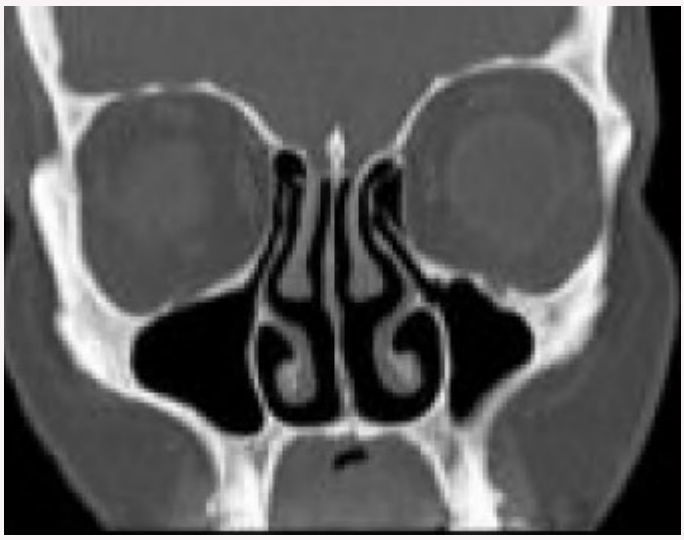
1. Chronic sinusitis SSali considered atrophic rhinitis to be infective in nature. He reported atrophic rhinitis in 7 children of a family after a child with atrophic rhinitis spent a night in their house. Common organism isolated from nasal cavities of these children was Klebsiella ozenae
2. Excessive surgical destruction of the nasal mucosa and turbinates
3. Nutritional deficiencies: Bernat in 1965 demonstrated that 50% of patients with atrophic rhinitis benefited with iron therapy. Hansen demonstrated symptomatic improvement in majority of this patients with atrophic rhinitis when treated with vitamin A.
4. Syphilis.
5. Endocrine imbalances (Disease is known to worsen with pregnancy / menstruation)
6. Heredity: This was first reported by Barton7 and Sibert (Autosomal dominant pattern of inheritance identified).
7. Autoimmune disease
8. Developmental: Hagrass reported shortened Antero Posterior nasal lengths and poor maxillary antral pneumatization in patients with atrophic rhinitis.
9. Vascular: Excess sympathetic activity was observed in these patients by Ruskin

Radiological features:

Radiologic features are similar for both types of atrophic rhinitis. Plain xrays show lateral bowing of nasal walls, thin or absent turbinates and hypoplastic
maxillary sinuses.

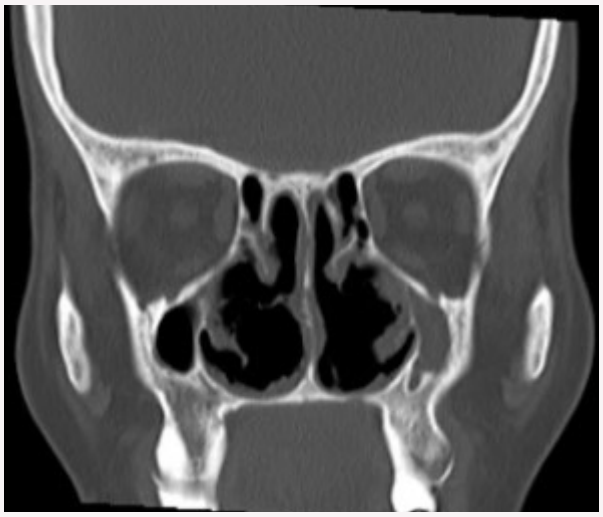
CT scan findings:

1. Mucoperiosteal thickening of paranasal sinuses
2. Loss of definition of osteomeatal complex due to resorption of ethmoidal bulla and uncinate process
3. Hypoplastic maxillary sinuses
4. Enlargement of nasal cavity with erosion of the lateral nasal wall
5. Atrophy of inferior and middle turbinates



Coronal CT image of nose and sinuses showing classic changes of atrophic rhinitis

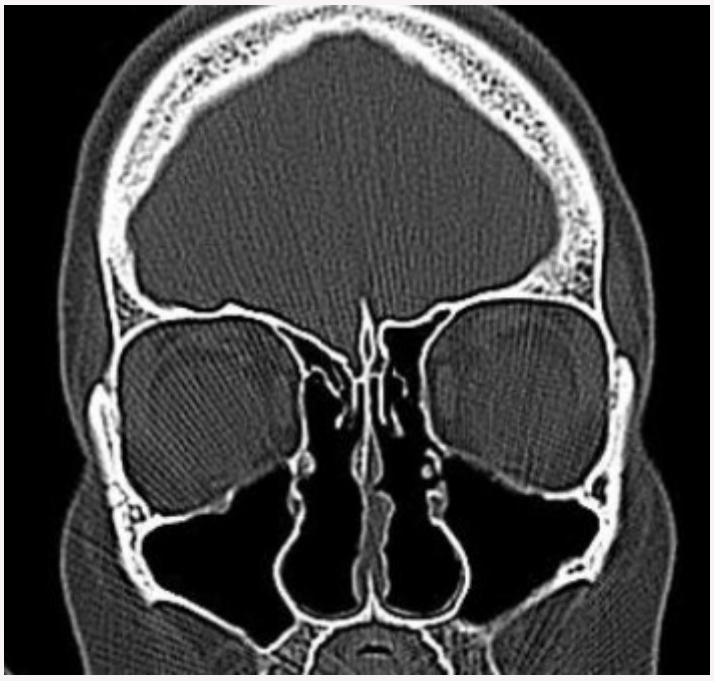
coronal CT scan plain of Nose and paranasal sinuses.
It shows thinned nasal mucosal lining.
The turbinates appear to be atrophic.
The nasal cavities appear to be excessively roomy on both sides.



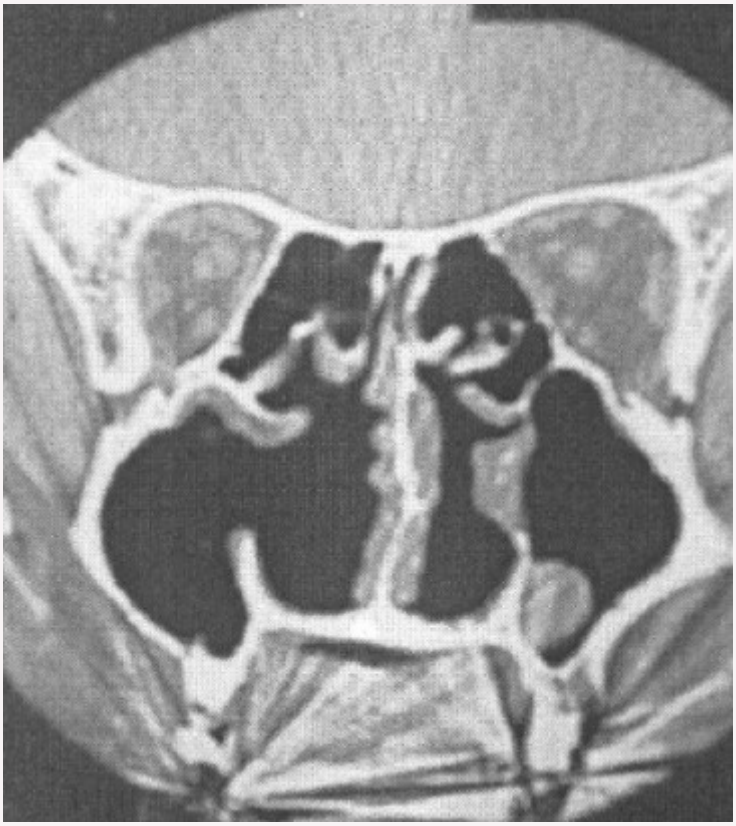
Coronal CT of nose and sinuses showing atrophied nasal mucosa with atrophied turbinates on both sides. Note the roomy nasal cavity. These are all the features of atrophic rhinitis.

Coronal CT of nose and sinuses showing atrophy of nasal mucosa, turbinates and lateral bending of the lateral nasal wall. The nasal cavity appears roomy suggesting the diagnosis of atrophic rhinitis

Axial CT of nose and sinuses showing atrophy of nasal mucosa, turbinates with associated roomy nasal cavity which are the features of atrophic rhintis



Coronal CT showing features of empty nose syndrome which is a sever form of atrophic rhinitis caused by surgery. Note the roomy nasal cavity with evidence of radical turbinate reductive surgery. Only the vestiges of the turbinates have been preferred.



Coronal CT showing widely patent nasal cavities with absent turbinates. Note a widened right maxillary sinus ostium indicating previous surgical procedure. This is a classic case of Empty nose syndrome.

Coronal CT showing widely patent middle meatal antrostomy with evidence of middle turbinate and partial inferior turbinate resection. These patients are potential candidates for empty nose syndrome

Rhinolith

Introduction:

Rhinoliths are calcareous deposits (stone like) inside the nasal cavity. These stone like structures are highly friable and may crumble when crushed. Rhinoliths are also known as nasal calculi are calcareous deposits present inside the nasal cavity.

Rhinoliths are of two types: Exogenous and Endogenous.

Exogenous rhinolith: If concretions occur around a impacted foreign body then it is considered to be exogenous in nature. These calcareous deposits around intranasal foreign bodies is the most common variety of rhinolith.

Endogenous rhinolith: If concretions occur around blood clot / inspissated foreign body then it is considered to be endogenous in nature. This condition is commonly diagnosed by history and anterior rhinoscopy.

This condition is common in adults and elderly individuals. Unilateral foul smelling blood tinged nasal discharge in an adult should always raise suspicion of rhinolith. Since rhinoliths are commonly seen in the anterior nasal cavity, anterior rhinoscopic examination of nose clinches the diagnosis.

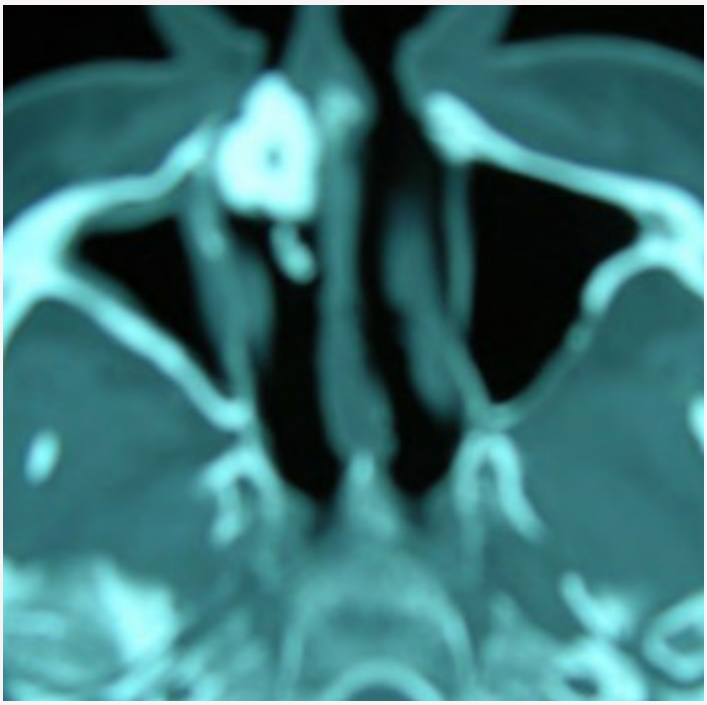
Patients with rhinolith usually present with:

1. Unilateral nasal obstruction
2. Unilateral foul smelling blood tinged nasal discharge
3. Hard mass inside the nasal cavity

The term rhinolith is derived from Greek (rhino – nose lithos – stone). It is considered to be a rather rare condition i.e. About 1 in 10,000 otolaryngologypatients. It was Bertholin who first gave the accurate description of this condition in 1654.
Rhinoliths are usually irregular brownish / grey colored mass
es present in the anterior portion of the nasal cavity.
For some unknown reason males seem to be co mmonly affected than females. The exact pathogenesis involved in the development of rhinolith is still not known. It has been suggested that impacted foreign body / mucous plugs / blood clot may incite inflammatory reaction and stimulate deposition of minerals and salts. The salts which gets deposited around the nidus is derived from nasal secretions, tear and inflammatory exudate. The nidus of rhinolith is usually a foreign body.

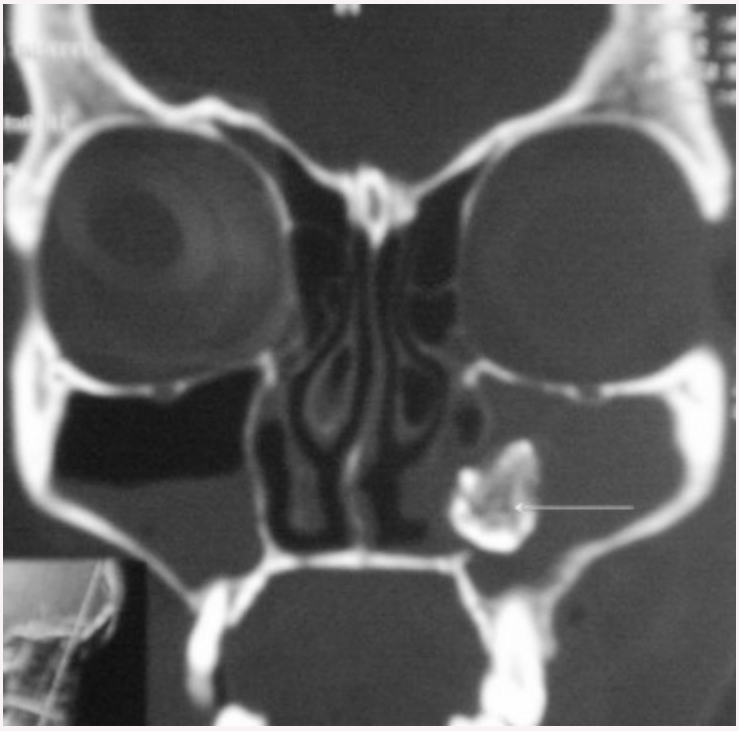
Even gauze swabs inadvertently left inside the nasal cavity following surgery has been known to cause rhinolith. Radiology is usually diagnostic. Typical radiological picture is radio opacity with

Coronal CT of nose and sinuses showing radio opaque mass occupying the floor of right nasal cavity (Rhinolith)



Axial CT of nose and sinuses showing rhinolith

sometimes central opacity. The central radiolucency could be due to the presence of organic material which could have formed the nidus for rhinolith. This description was first given by Mac Intyre in 1900. CT scan usually cannot differentiate rhinolith from other calcified masses.



Coronal CT of nose and sinuses showing antrolith. (A radio opaque irregular mass could be seen within left maxillary antrum).

Antroliths:

These are calcifieed bodies within the antral cavity. The occurrence of true antroliths is very rare. Usually it begins with an antral foreign body which constitutes the central core of the antrolith. The central core is usually endogenous and rarely of exogenous origin. The core could be:

Tooth fragments

Blood fragments

Pus

Mucous

Fungi

Exogenous niduses could be composed of different materials like:

Cotton

Cellulose

Paper

Snuff

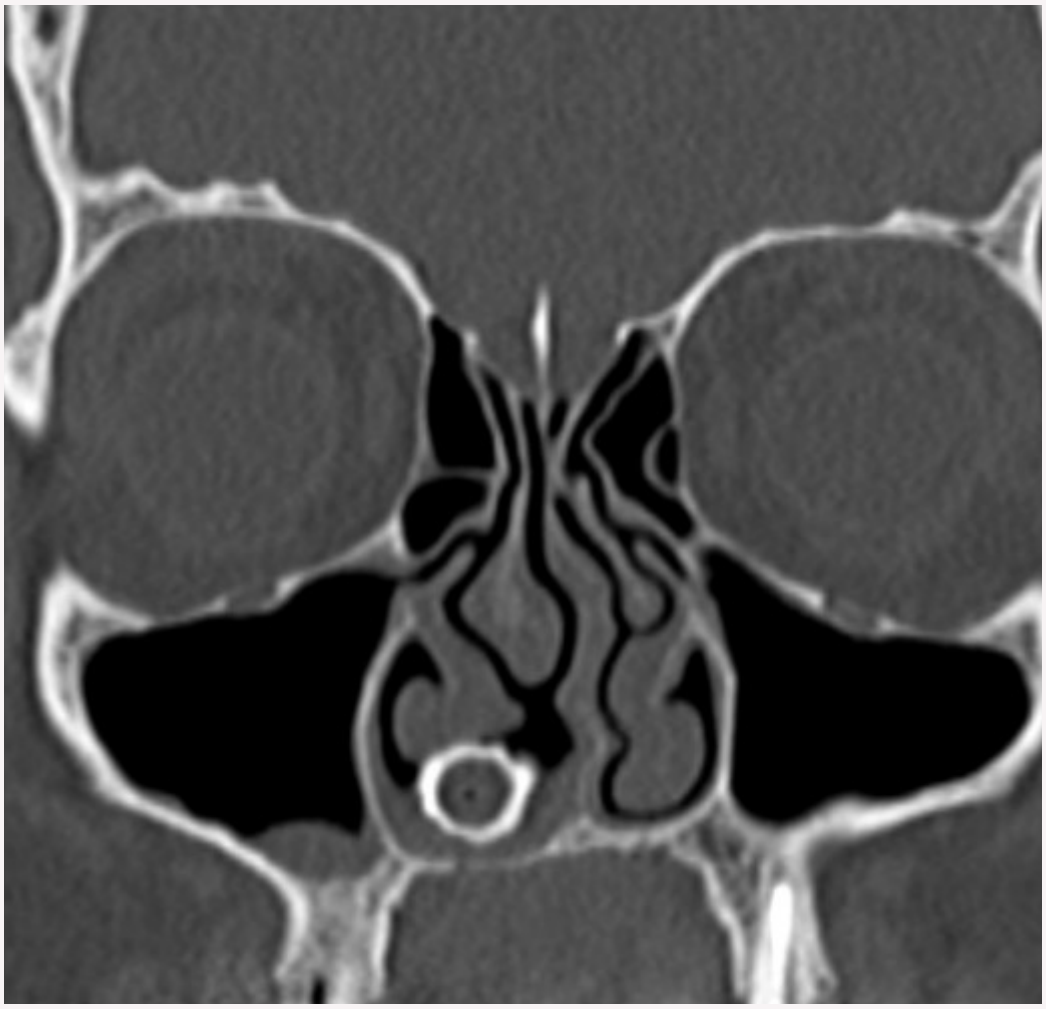
Dental burr bits

Match stick

Most important predisposing factor seems to be long standing infection, poor sinus drainage and presence of foreign body within the sinus cavity.

Coronal CT showing a calcified, hyperdense irregularly shaped mass in the left ethmoid region abutting into the sphenoid sinus. Note associated inflammation inside sphenoid sinus.

Axial CT image showing calcified hyperdense irregularly shaped mass in the left ethmoid region bulging into the sphenoid sinus.



Coronal CT showing rhinolith in the floor of the right nasal cavity. The central radiolucency could probably be caused by inspissated mucin / blood clot.

Rhinosporidiosis

Introduction:

Rhinosporidiosis has been defined as a chronic granulomatous disease characterised by production of polyps and other manifestations of hyperplasia of nasal mucosa. The etiological agent is Rhinosporidium seeberi.

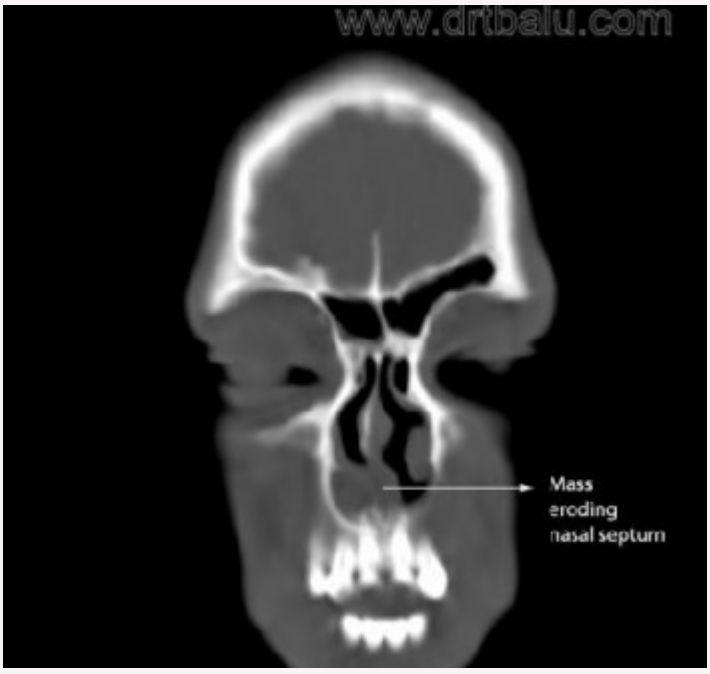
Rhinosporidium seeberi: was initially believed to be a sporozoan, but it is now considered to be a fungus and has been provisionally placed under the family Olipidiaceae, order chritridiales of phycomyetes by Ashworth. More recent classification puts it under DRIP'S clade. Even after extensive studies there is no consensus on where Rhinosporidium must be placed in the Taxonomic classification. It has not been possible to demonstrate fungal proteins in Rhinosporidium even after performing sensitive tests like Polymerase chain reactions.

A separate chapter has been dedicated to this condition because it is uniquely common in south east Asian countries. Unless anterior cuts of CT scans of nose and sinuses are interpreted with care and caution this condition can invariably be missed radiologically.

Clinical features:

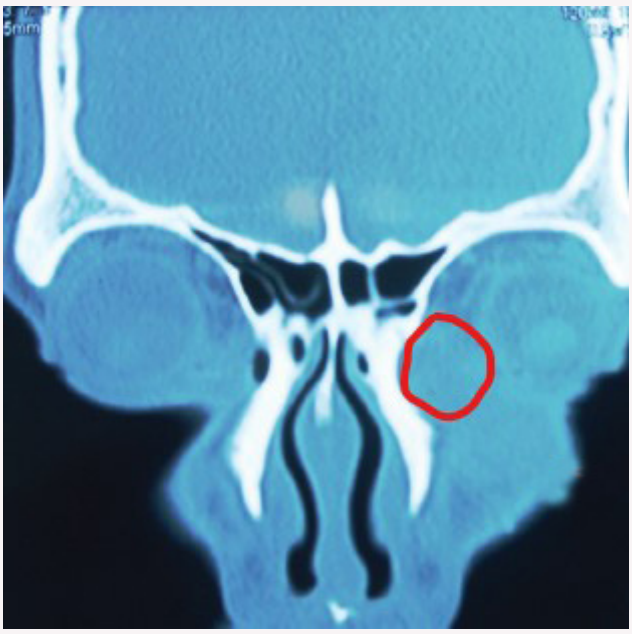
Patients usually present with bleeding from the nose. Lesions in the nose can be polypoidal, reddish and granular masses. They could be multiple pedunculated and friable. They are highly vascular and bleed easily. Their surface is studded with whitish dots (sporangia). They can be clearly seen with a hand lens. The whole mass is covered by mucoid secretion. The rhinosporidium in the nose is restricted to the nasal mucous membrane and does not cross the muco cutaneous barrier.

Coronal CT of nose and sinuses showing soft tissue mass involving the entire right nasal cavity. Note involvement of lacrimal sac also close to the medial canthal area



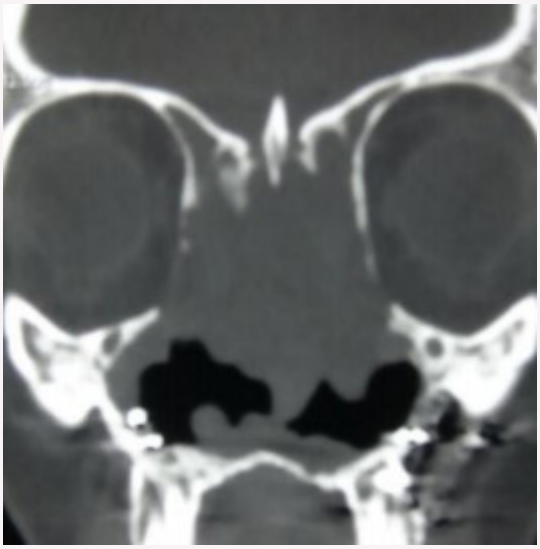
Coronal CT image of nose and sinuses showing soft tissue lesion in the right inferior me atus.

The role of imaging in rhinosporidiosis is to evaluate the number of lesions, the location and extent of disease, surrounding bone involvement, nasolacrimal duct involvement.



Coronal CT showing diffuse swelling over left medial canthus and floor of the orbit. (Red circle).

Coronal CT image of paranasal sinuses Bone window showing soft tissue density in the inferomedial portion of right eye with extension into nasolacrimal duct. Note: Expansion of nasolacrimal duct with rarefaction of its walls.



Coronal CT showing soft tissue mass occupying both nasal cavities obstructing frontal sinus drainage. Nasal septum is also involved. Diagnosis - Rhinosporidiosis

Malignant tumors of nose and nasopharynx

Introduction:

Malignant tumors of nose and paranasal sinuses constitute about 1% of all malignant tumors1. These tumors also constitute about 3% of head and neck malignancies. Malignant tumors of maxilla are more common in males in fact twice as common as in females. They are commonly diagnosed in patients in the age group of 50–70 years.

Histologically the commonest type of malignancy in this area is squamous cell carcinoma. Other histological types like adenocarcinoma, sarcomas, neuroblastomas, lymphomas and malignant melanomas are rare4. These tumors are very difficult to treat because:

1. Of the complex adjacent anatomy (orbit, skull base etc)
2. These patients present fairly in the late stage of their disease

Among the sinus malignancies, maxillary sinus malignancy happens to be the commonest, followed by ethmoids and sphenoid sinuses.
Malignant tumors involving maxilla has poor prognosis because they present late.

Malignant lesions involving sinuses have a propensity to spread via areas of least resistance. This spread could involve adjacent vital areas like:

1. Orbit
2. Anterior skull base
3. Pterygopalatine fossa
4. Spread into middle cranial fossa

Areas of least resistance include:

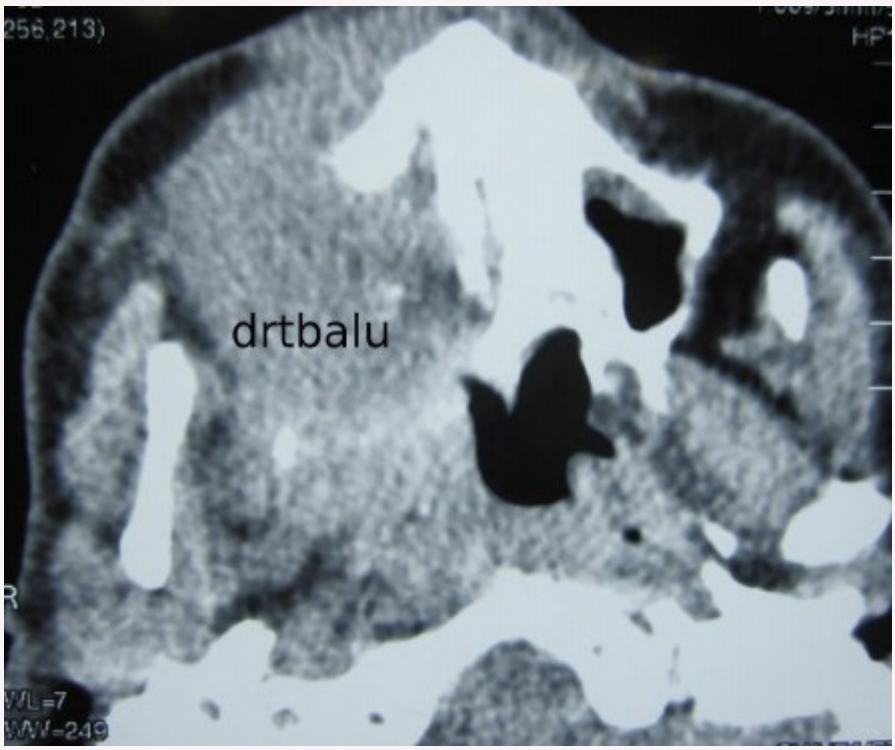
1. Medial wall of maxillary sinus
2. Inferior wall of orbit because it is weakened by the presence of neurovascular bundle

3. Anterolateral wall of maxilla to involve skin. Skin involvement indicates that the tumor is fairly advanced because nodal involvement is common in these patients.

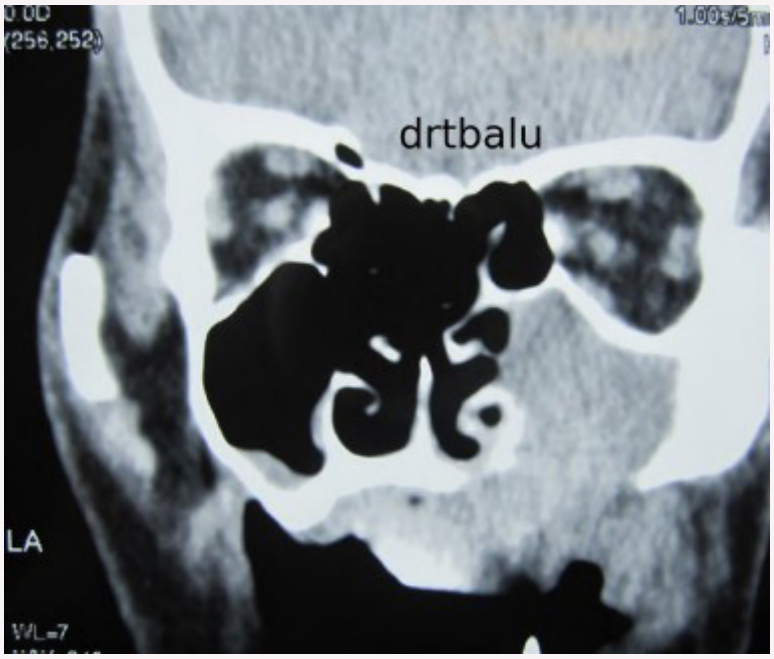
Roughly 70% of sinonasal malignancies occur in maxillary sinus 6. 20% of malignant tumors occur within the nasal cavity while the remaining 10% is constituted by ethmoid and sphenoid sinus malignancies.

Role of CT scan in patients with sinus malignancies include:

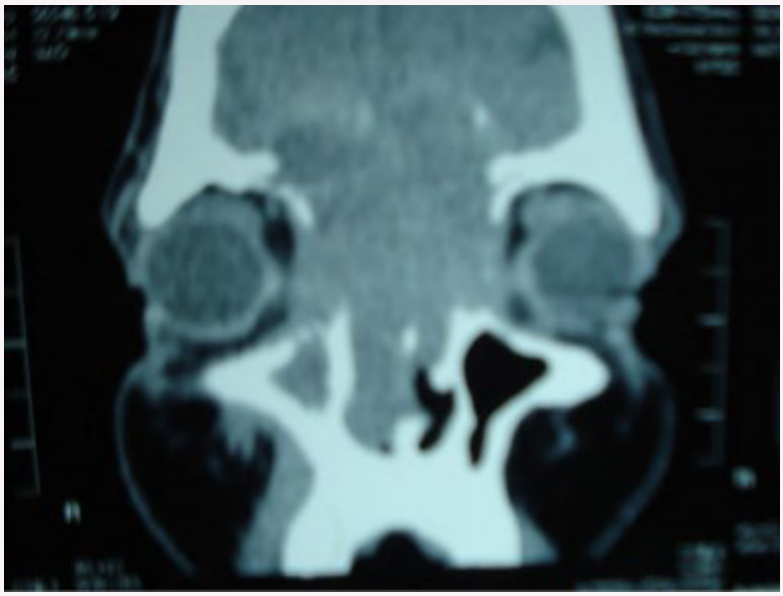
1. To assess the anatomical extent of the lesion
2. To look for involvement of critical areas like skull base and orbit whichcould drastically change the prognosis



Axial CT image showing expansile lesion involving right maxillary sinus with erosion of anterolateral wall of maxilla. Note erosion of posterior wall of maxilla with extension into pterygopalatine fossa. Pterygoid plates cannot be visualized on the right side



Coronal CT image of nose and sinuses showing mass lesion within left maxil lary sinus with erosion of palate



Coronal CT of nose and sinuses showing mass arising from right nasal cavity eroding na sal septum, involving the opposite side. Note erosion of anterior skull base. Right max illary sinus haziness is due to reactive sinusitis. Dural breach by the tumor can be identi fied only in a contrast CT or MRI. Cartilaginous portion of nasal septum resists malig nant erosion. In this picture the bony portion is eroded. Medial wall of right orbit has also been eroded

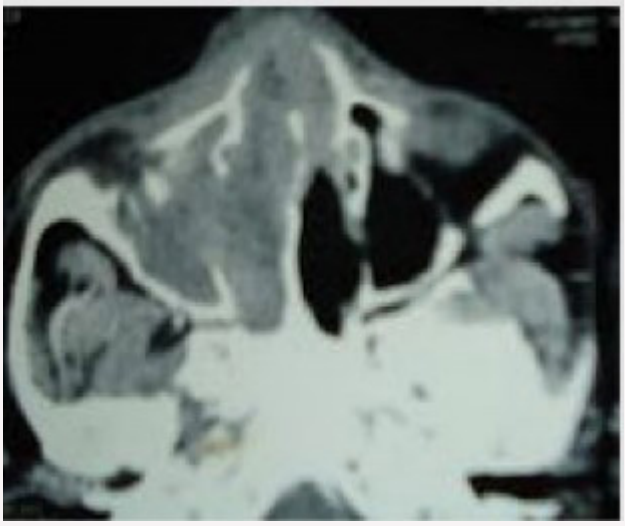
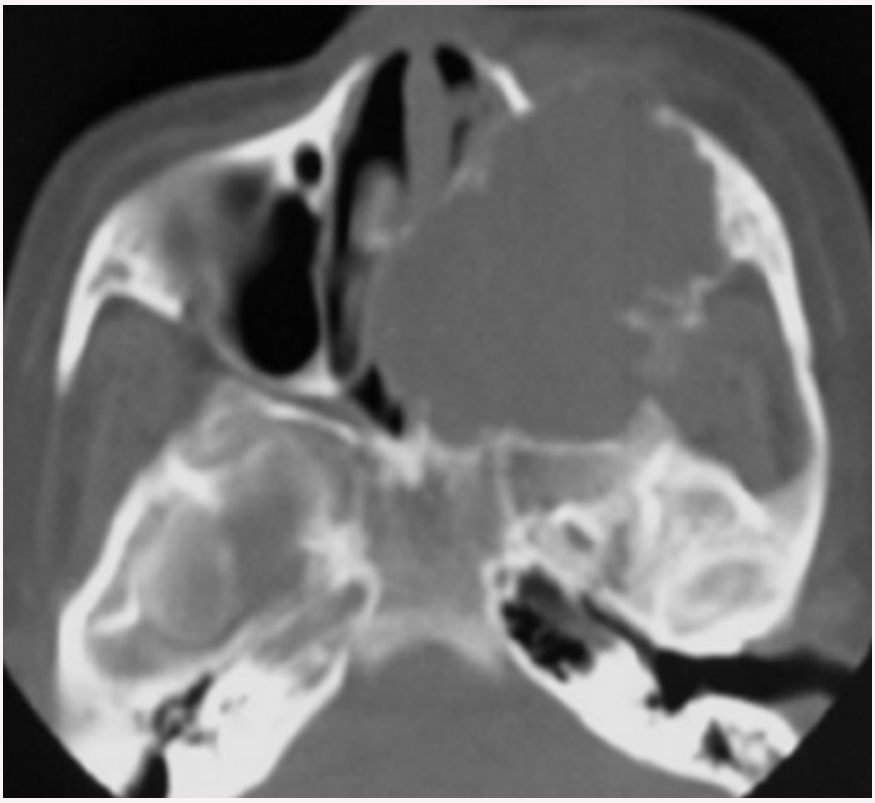


Image showing Axial CT of nose and sinuses showing malignant tumor arising from right maxilla eroding medial wall of maxilla to involve the nasal cavity. Note erosion of anter olateral wall of maxilla causing skin involvement

Coronal CT of nose and sinuses showing expansile, erosive lesion involving right maxil lary sinus. Note medial wall of maxilla has been destroyed. Alveolar margin of right maxilla has been partially destroyed. In these patients loosening of teeth could be a predominant symptom which should not be ignored.



Axial CT (bone window settings) showing tumor in the left side of the maxilla. Note erosion of anterolateral and medial wall of maxilla. The same mass could be seen filling the left nasal cavity.

Coronal CT showing expansile lesion involving left maxilla. Inferior wall of maxillal eroded and the same mass could be seen lifting the cheek. Erosion of medial wall of maxilla is also seen and the same mass could be seen presenting within the left nasal cavity. Note periosteal thickening around the tumor mass.

Commonest malignant lesion involving maxilla happens to be squamous cell carcinoma. Other malginant lesions that can affect maxilla include:

Osteosarcoma
Condrosarcoma
Ewings sarcoma
Fibrosarcoma
Hemanigoendothelioma and lymphomas